THE EFFECT OF ADDED ENERGY ON NITROGEN UTILIZATION AND DIGESTIBILITY OF WINTERING RATIONS BY STEERS

by

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INTRODUCTION

Roughages are the main source of energy in rations for wintering range beef cattle. Those most commonly used in Oklahoma are prairie hay and dry range grass. It is important that these roughages be supplemented with adequate protein for efficient digestion and utilization, and that the animal be furnished additional protein to meet its needs for various body functions. Ordinarily, the source of protein and other essential nutrients in a ration is more costly than the source of energy. Thus, the provision of protein for optimum balance of nutrients in cattle rations becomes a consideration of major economic importance.

There is only a limited amount of research on the effect of different sources and amounts of energy on protein (nitrogen) utilization. Experiments conducted _in vitro_ have shown that small amounts of readily-available carbohydrate may improve cellulose digestion by rumen microorganisms. Different sources and amounts of energy, _e.g._, simple sugars, complex carbohydrates and fats, seem to have different effects _in vitro_ and _in vivo_. In animals with simple stomachs, it has been shown that, under most experimental conditions, energy intake has a marked effect on protein utilization. It was deemed desirable to study the effect of adding different amounts and sources of energy (glucose, starch and corn oil) on nitrogen (protein) metabolism and on the digestibility of ration constituents by steers fed basal wintering-type rations. The results led to further studies of the effects of corn oil additions to the ration and mineral additions to the fermentation media on _in vitro_ cellulose digestion.

REVIEW OF LITERATURE

The Effect Of Fat On Digestibility, Nitrogen Retention And Feed Utilization

Munro (1951), in an extensive review, cites experiments conducted by European workers in the later part of the nineteenth century in which the addition of fat or carbohydrate to ruminant rations generally increased nitrogen retention.

Previous Oklahoma Work

Robinson (1958) studied the effect of fat on digestion and nitrogen utilization by ruminants. He used eight Hereford steers fed a basal wintering-type ration of 3000 gm prairie hay, 454 gm cottonseed meal, 25 gm dicalcium phosphate and 25 gm salt. Half of the steers received, in addition, 200 gm of refined corn oil as a source of fat. The corn oil which was mixed with the cottonseed meal reduced the average protein content of the basal ration from 10.1 to 9.6 percent. This addition of oil decreased daily urinary nitrogen excretion from 17.45 to 15.45 gm without appreciably changing fecal nitrogen excretion. Total nitrogen retention was significantly increased ($P < 0.05$) from 21.1 percent of the intake to 24.7 percent. However, the corn oil addition significantly decreased the apparent digestibility of crude fiber and nitrogen-free extract. The digestibility of all other ration nutrients except ether extract was reduced, but not significantly; ether extract digestibility was significantly increased. It appears from these results that the addition of 5 percent (200 gm) corn oil to this wintering-type ration produced a true protein-sparing action.

Hubbard (1957) also studied the effect of added fat on nitrogen utilization and digestibility by steers. In this experiment, 10 percent (400 gm) corn oil was added to a basal ration of 3000 gm hay, 50 gm minerals (dicalcium phosphate and salt, 1:1), 585 gm cottonseed meal, and 323 gm corn; protein was reduced from 11 to 10 percent. The addition of corn oil decreased daily urinary nitrogen from 23.2 to 22.3 gm and increased fecal nitrogen from 27.9 to 28.6 gm. Neither of these changes was statistically significant. Nitrogen retention (balance) was unchanged. Thus, this large amount of oil added to a higher energy ration failed to produce a protein-sparing effect. The oil reduced the digestibility of organic matter, protein, crude fiber and nitrogen-free extract. Ether extract digestibility was significantly increased.

Balance and Digestion Trials

Lucas and Loosli (1944) studied the effect of added fat upon the digestibility of other ration nutrients by dairy cattle. In all trials timothy hay and beet pulp were fed with a concentrate mixture. The hay, beet pulp and concentrates were fed in the ratio of 7 to 8 to 10 parts by weight, respectively. The only mineral supplement was 1 percent salt added to the concentrate mixture. They found that the digestibilities of dry matter, nitrogen-free extract and crude fiber were reduced when the ether extract content of the diet was increased from 1 to 7 percent by the addition of corn oil or soybean oil. Crude protein digestibility was not significantly altered by the fat additions.

Swift *et al.* (1947) studied the effect of corn oil on apparent digestibility of a fattening-type ration fed to sheep. The basal ration contained 420 gm mixed hay (alfalfa and timothy of excellent quality) 420 gm corn meal, and 48 gm linseed meal. The addition of 34 gm (4 percent) of corn oil increased the apparent and true digestibility of every feed constituent, with the greatest increase in protein digestibility. However, when the amount of corn oil was doubled all of the digestion coefficients, except that for ether extract, were reduced to values below those obtained with the basal ration. The authors state that this clearly shows that the larger amount of fat is above the optimum for sheep under the conditions of this experiment. In fact, the addition of the second 34 gm of corn oil (319 Calories of gross energy) increased the digestible energy of the ration by only 83 Calories.

A further study was conducted by Swift _et al_. (1948) with the same basal ration (Swift _et al_., 1947). The primary purpose of this study was to determine the optimum amount of fat in rations for sheep. They fed six rations containing 3, 4, 5, 6, 7 and 8 percent ether extract. They found that as the fat content of the ration was increased by the substitution of corn oil for soluble carbohydrate (glucose) the percentage digestibility of the ether extract increased in a regular manner. Similarly, the digestibility of the nitrogen-free extract decreased regularly with each addition of fat. There was a definite trend toward a decrease in the digestibility of dry matter with increased fat in the ration. They found that when rations differed by 3 percent of fat the differences in digestibility were statistically significant. No consistent effect on digestibility of protein or crude fiber was obtained by these workers.

Brooks _et al_. (1954) reported the effect of corn oil and lard on the digestion of cellulose and crude protein by sheep fed rations based on cottonseed hulls. Three digestion trials were conducted by the chromium oxide indicator method with 20 crossbred yearling wether lambs in each trial. The basal ration supplemented with 2500 I. U. of vitamin A contained 908 gm cottonseed hulls, 94 gm casein and 6 gm chromium oxide. The sheep had free access to salt and a mineral mixture made up of equal parts salt, ground limestone and dicalcium phosphate. All sheep lost weight during the trial, but the weight loss was greater for sheep fed the corn oil than for those fed the basal ration. The coefficients of digestibility of cellulose and protein were reduced 52 and 17 percent, respectively, by the addition of 32 gm (3.2 percent) of corn oil. These sheep developed mild anorexia and consumed only 87 percent as much feed as those in the basal lot during the last part of the feeding period. Those fed 64 gm of corn oil daily consumed only 80 percent as much feed as the basal lot. They scoured and appeared listless. The coefficients of digestibility of cellulose and protein were reduced 70 and 36 percent, respectively. Sheep receiving 32 gm of lard per day digested 33 percent less cellulose than those on the basal ration. There was no apparent loss of appetite and little change in the digestibility of protein, but a marked decrease in cellulose digestion was noted. Sheep receiving 64 gm of lard did not scour or appear listless, but their feed intake was reduced 6 percent. The coefficient of digestibility of cellulose was 62 percent lower than in sheep fed the basal ration, and the coefficient of digestibility of protein was decreased 33 percent. The authors concluded that large amounts of fat should not be added to high-fiber rations if maximum cellulose and protein digestion is desired. Corn oil was more effective than lard in reducing digestibility of cellulose and protein.

Hale and King (1955) studied the effect of added fat on the digestibility of rations by lambs. Corn oil, prime tallow and hydrogenated animal fat were added at 0, 4, 8 and 12 percent levels to the ration. The basal ration was not given but was referred to as a standard lamb fattening ration. The added fat replaced an equal amount of corn in the ration. The 4 percent addition had little, if any, effect on digestibility of dry matter. The two higher levels particularly when corn oil was used, markedly reduced dry matter digestibility.

Erwin et al. (1956b) studied the effect of different feed additives on digestibility of dry matter, crude fiber, ether extract and protein by steers. They found that the addition of 7 percent fat (bleachable fancy tallow) to either a high alfalfa hay or a high straw ration significantly ($P < 0.01$) reduced the digestibility of dry matter and crude fiber.

Rhodes et al. (1956) found that when corn oil in amounts of 1.8, 3.0 and 4.2 percent of the ration replaced corn syrup in rations containing 65 to 80 percent cottonseed hulls, the digestibility of protein and cellulose was significantly decreased. Nitrogen retention paralleled protein digestibility.

In two metabolism trials Summers et al. (1956) fed six groups of wethers (4 per group) distilled water and a semi-purified basal ration composed of corncobs (65 and 80 percent), Drackett protein, urea, corn syrup, iodized salt, dicalcium phosphate, magnesium sulfate, sulphur and vitamins A and D. In trial I, 3 percent corn oil added with 30 gm of alfalfa ash did not affect digestibility of cellulose. Nitrogen retention was not affected. In trial II alfalfa ash (30 gm) added alone significantly improved cellulose digestibility, protein digestibility and nitrogen retention; corn oil (2 percent) added alone significantly depressed the digestibility of cellulose and protein; this effect was completely reversed and nitrogen retention was significantly improved when alfalfa ash was added to the corn oil ration.

Pfander and Verma (1957) studied the physical factors that influence the response of sheep to added corn oil. Twelve mature fistulated crossbred wethers were fed, in grams per day: Cottonseed hulls, 900; casein, 90; calcium diphosphate, 9; salt, 10; and vitamin A and D source, 1.3. Digestibility trials were based on six-day total collections following 14-day preliminary periods. The sheep were divided into three equal groups of four each. One group was used as a control and fed the basal ration. The treatment groups were fed 46 gm of corn oil, mixed with the cottonseed hulls before feeding or poured into the rumen after feeding. The coefficients of digestibility of the basal ration, the ration with fat added to the hulls, and with fat through the rumen fistula were, respectively: organic matter, 50, 35 and 50; cellulose, 52, 29 and 49; nitrogen, 51, 35 and 50. Digestibilities were significantly lower when corn oil was mixed with the cottonseed hulls before feeding; however, pouring the same quantity of corn oil into the rumen after feed did not significantly affect digestibility. Samples of rumen ingesta were removed after each trial at 0, 5.5 and 12 hours after feeding. Fermentation was stopped and the fat was extracted. Within five hours after feeding, the corn oil had been hydrogenated to the extent that it was solid at room temperature.

Ward *et al.* (1957) conducted two growth trials and four digestion trials to study the effect of added corn oil, with and without alfalfa ash, upon the digestibility and utilization of rations containing from 35 to 85 percent ground corncobs or cottonseed hulls. The rations fed varied from semi-purified diets to rations containing all natural feedstuffs.

All basal rations contained salt and dicalcium phosphate. However, additional minerals were added in some of the trials. These minerals were monobasic sodium phosphate, sodium sulfate, cobalt sulfate and calcium carbonate. Western-type wethers were used in all trials except for one digestion trial with Hereford steers. In the growth trials with wethers, addition of either 2.6 or 10 percent corn oil reduced rate of gain and feed efficiency. The addition of 28 gm of alfalfa ash completely counteracted the detrimental effect of the 2.6 percent level of corn oil and partially counteracted the effect of the 10 percent level. Alfalfa ash was as effective as alfalfa meal. In the digestion trials with sheep, addition of 2.4 percent corn oil to a semi-purified diet containing 55 percent cottonseed hulls did not affect the digestibility of any components except ether extract. The addition of 3.5 percent corn oil to this ration, or the addition of 3 percent to a basal ration containing corncobs, caused a significant reduction in the digestibility of dry matter and all ration components except ether extract and also caused a reduction in nitrogen retention. The addition of alfalfa ash partially alleviated the effect of corn oil upon digestibility and significantly improved nitrogen retention when compared to the basal ration or the ration supplemented with corn oil alone. Alfalfa ash improved only slightly the digestibility of the low-fat basal rations used in these trials.

Grainger _et al_. (1957) conducted three digestion trials with four wethers in each treatment group. The feeding regimen included distilled water and a semi-purified basal ration composed of corncobs (65 percent), Drackett protein, urea, corn starch, corn syrup, iodized salt, dicalcium phosphate, magnesium sulfate, sulphur and vitamins A and D. In trial I, 6 percent corn oil replacing corn syrup significantly decreased the digestibility of organic matter, cellulose and protein; 5 percent significantly decreased organic matter and protein digestibility. A trace mineral mixture containing iron, copper, cobalt, manganese, zinc and molybdenum equivalent to the amounts contained in 30 gm alfalfa ash reversed the effect on protein digestibility but not on organic matter and cellulose digestibility. In trial II, a significant depression of organic matter and cellulose digestibility by 5 percent corn oil was reversed by alfalfa ash, calcium or calcium and phosphorus equal to that contained in alfalfa ash. The sources of calcium and phosphorus were not given. The addition of calcium or calcium and phosphorus to the corn oil ration significantly improved the digestion of protein. Adding trace minerals or phosphorus to the corn oil ration did not alleviate the depression of digestibility of the organic matter or cellulose. In trial III, either calcium or calcium and phosphorus completely reversed the depression of organic matter and cellulose digestibilities produced by 5 percent corn oil. Calcium and phosphorus significantly improved the digestion of protein when added to the corn oil ration. Calcium or calcium and phosphorus did not improve the digestibility of the basal ration. Corn oil apparently increased the requirement for calcium by sheep.

Brethour et al. (1958), in growth and digestibility studies with sheep, found that the inclusion of a high level of animal fat, 15 percent, in a basal fattening-type ration containing 35 percent cottonseed hulls supplemented with milo, cottonseed meal and minerals (dicalcium phosphate, calcium carbonate and salt in 1:1:1 ratio) significantly reduced the digestibility of organic matter, and decreased weight gains. The addition of alfalfa ash, sodium bicarbonate or potassium bicarbonate to the high fat ration did not improve weight gains; in fact, both bicarbonates tended to depress appetites and gains. In another experiment, it was shown that the addition of 10 percent corn oil reduced gains regardless of whether it was added to the concentrate or roughage portion of the ration before feeding.

White et al. (1958) conducted three digestion trials with mature wethers fed semi-purified diets. The cellulose in the diets was supplied either by corncobs or cottonseed hulls. The purpose of the experiment was to study (1) the effect on cellulose digestibility of prolonged supplementation of a ration with fat, and the subsequent rate of recovery following a ration change, and (2) the active component in alfalfa ash that reverses the depressed digestibility caused by supplemental fat. Five percent corn oil progressively decreased cellulose digestion during the first 40 days of Trial 1. Recovery of cellulose digestion was not complete until 17 days after the omission of corn oil. In Trials 2 and 3, 30 gm of alfalfa ash restored digestion of cellulose in a ration that contained 5 percent corn oil. A similar effect was produced by 4.4 gm calcium, or 4.4 gm calcium and 0.86 gm phosphorus. Calcium was added as calcium carbonate and phosphorus was added as phosphoric acid. The addition of phosphorus (0.86 gm) alone or a trace mineral mixture which contained copper, molybdenum, manganese, cobalt, iron, zinc and boron to the corn oil ration was ineffective in restoring the digestion of cellulose. The effect of phosphorus and trace minerals added to the basal ration alone was not determined.

Tillman and Brethour (1958) used 12 wether lambs each weighing approximately 75 pounds to determine the effects of corn oil upon the utilization of dietary calcium and phosphorus. The basal ration contained 25 percent cottonseed hulls, 15 percent alfalfa meal, 8 percent soybean oil meal, 40 percent ground corn, 5.45 percent corn starch, 5.45 percent corn sugar, vitamins A and D, salt and dicalcium phosphate. In the corn oil ration 7.5 percent corn oil replaced 3.75 percent corn starch and 3.75 percent corn sugar. The comparative balance and isotope dilution procedures were used to determine the fecal endogenous calcium and phosphorus excretions. The inclusion of 7.5 percent corn oil in a ration in which the major portion of the cellulose was supplied by cottonseed hulls did not significantly affect the apparent digestibility, fecal endogenous excretion, true digestibility, or retention of dietary phosphorus. Neither did it affect the fecal endogenous or urinary excretion of dietary calcium. This level of corn oil, however, significantly reduced both the apparent and true digestibility of dietary calcium, the cumulative effect being a decrease in the retention of dietary calcium which closely paralleled the increase in the fecal excretion of calcium.

Davison and Woods (1959) conducted a series of digestibility studies with lambs to determine the effects of corn oil, corn oil saponified with potassium hydroxide, corn oil plus calcium carbonate and calcium carbonate upon digestibility of a ration composed of ground corncobs, 45 percent; ground shelled corn, 32 percent; corn gluten meal, 20 percent; salt, 1 percent; dicalcium phosphate, 1 percent; and vitamin A and cobalt added. Both corn oil and corn oil saponified with potassium hydroxide were found to decrease the digestibility of dry matter, organic matter, protein and cellulose, and to increase the digestibility of ether extract. Corn oil decreased the digestibility of ash. Calcium carbonate largely overcame the depressing effects of corn oil on digestibility when added to the corn oil ration and resulted in an increase in digestibility of dry matter, organic matter, protein and cellulose when added to the basal ration. The addition of calcium carbonate tended to increase nitrogen retention in both the basal and basal plus corn oil rations. In related experiments, _in vitro_ magnesium carbonate was as effective as calcium carbonate in partially alleviating the depressing effects of corn oil upon cellulose digestion.

Production Trials

Jones _et al_. (1942) fed steers a fattening ration containing approximately 6 percent cottonseed oil and reported the oil to be a satisfactory source of energy.

Willey and associates (1952) fed steer calves the following type rations: low fat-low energy, low fat-high energy, high fat-low energy and high fat-high energy. Fat levels measured as ether extract ranged from 2.84 percent in the low level ration to 7.54 percent in the high level ration. The efficiency of feed utilization was greater on the high-fat ration than on the low-fat ration and appeared to be independent of the energy level.

In a Nebraska test, Matsushima _et al_. (1953) fed steers a pelleted standard corn belt fattening ration (alfalfa hay, ground shelled corn and soybean oil meal) containing (1) no added fat, (2) 5.5 percent beef tallow and (3) 5.5 percent corn oil. The average daily gains of steers fed these three rations were 2.11, 2.00 and 1.70 lbs, respectively. The authors stated that the corn oil became rancid and this rancidity probably was the cause of an observed decrease in feed consumption. Matsushima and associates (1955), in a continuation of this work, states that the energy from high grade inedible fat was utilized almost as effectively as the energy from corn when the level of fat did not exceed one pound per day. Some digestive disturbances were observed when the animals were fed one and one half pounds daily.

Schweigert and Wilder (1954) fed two lots of 12 steers each a fattening ration of corn, dried brewers' grain, molasses, minerals and hay. One pound of stabilized fat which replaced 2.5 lbs of corn in the basal ration was fed to the second group of steers. The animals were on trial 109 days and then slaughtered. Rate of gain and carcass grade was approximately the same for both groups. When the ration contained fat the total feed intake was reduced resulting in the same caloric intake for each ration. The authors were trying to evaluate caloric utilization from the fat as compared to corn rather than the economy of gain for each group on full feed. These researchers concluded that since carcass grades and rates of gain were almost the same for both groups, the animal fat had an energy values two and one-half times that of the corn.

Kammlade and Butler (1954) conducted a fattening experiment with lambs in which they added fat (special grade tallow) at the 0, 5, 10 and 15 percent levels. All four rations contained 7.5 percent cottonseed meal, 10.0 percent molasses and 45.0 percent alfalfa hay. An equal amount of sorghum grain was replaced by each fat addition and the percent sorghum grain in the rations containing 0, 5, 10 and 15 percent fat was 37.5, 32.5, 27.5 and 22.5, respectively. They obtained greater feed efficiency and lowered cost of gain for lambs fed rations containing 5 and 10 percent fat. There were no significant differences among gains or carcass weights of any of the groups.

Hentges _et al_. (1954) conducted an experiment which indicated that waste beef fat could satisfactorily replace up to 5 percent of the concentrate in steer fattening rations. The ration used in this experiment was not given. These workers conducted a 154-day feeding trial in which they fed rations containing 0, 5 and 10 percent additional fat. These rations produced daily gains of 1.8, 1.9 and 1.5 lbs, respectively.

Erwin et al. (1956a) studied the effect of 7 percent fat (bleachable fancy tallow) and low-quality roughage diets fed to steers. In the 183-day feeding period, they found that the addition of 7 percent fat significantly increased rate of gain of steers fed rations ranging from 50 to 83 percent alfalfa hay, and that it significantly reduced the rate of gain of steers fed rations containing the same quantities of wheat straw.

Matsushima et al. (1957) compared the performance of animals fed different levels of energy with varying levels of protein in beef cattle fattening rations. The feeds used were chopped alfalfa hay, ground shelled corn, ground corncobs, dried molasses, soybean oil meal, urea and tallow. All rations contained 15 percent chopped alfalfa and the other ration components were varied to obtain the desired protein and energy content. A total of nine different treatments or rations were included in this test. These rations contained three levels of protein low, medium or high. The medium level was that recommended by the National Research Council. The rations with the low level of protein were calculated to be approximately 18 percent below the recommended level and those with the high level of protein were approximately 18 percent above the recommended level. These rations were adjusted to provide different levels of energy (low, medium and high) within each level of protein. The medium level of energy was the recommended level (National Research Council) while the low level was 11 percent below the recommended level, and the high level about 11 percent above the recommended level. The largest gains were made by the steers fed rations with the medium level of energy and medium or high level of protein. The most efficient gains were made by the steers fed rations with the high level of energy and the medium or high level of protein.

Increasing the ether extract of a ration by adding fat appears to have varied effects on ration nutrient digestibility and feed utilization, depending on kind of roughage in the ration (Erwin et al., 1956a), mineral supplements (Summers et al., 1956; Ward et al.,1957; Grainger et al., 1957; White et al., 1958; Davison and Woods, 1959), quality of fat (Brooks et al., 1954; Matsushima et al., 1955; Hale and King, 1955) and quantity of fat (Swift et al., 1947). The addition of 3 to 5 percent fat (corn oil) to rations containing low quality roughages such as cottonseed hulls and corncobs usually decreases nitrogen retention and digestibility of all ration nutrients except ether extract (Rhodes et al., 1956; Summers et al., 1956; Ward et al., 1957; Grainger et al., 1957; White et al., 1958). When similar quantities of fat (corn oil) are added to rations containing prairie hay or higher quality roughage, nitrogen retention has been found to increase (Robinson, 1958) and digestibility varies from an increase in all ration constituents (Swift et al., 1947) to a decrease in crude fiber and nitrogen-free extract (Erwin et al., 1956b; Hubbard, 1957).

Levels of fat not exceeding 5 percent have been found to be satisfactory sources of energy in rations fed to fattening sheep and steers when weight gain and feed efficiency were used as criteria of value (Matsushima et al., 1953, 1955, 1957; Schweigert and Wilder, 1954; Hentges et al., 1954). Higher levels of fat were found to be unsatisfactory. However, other investigators have reported satisfactory gains by sheep (Kammlade and Butler, 1954) and steers (Jones et al., 1942; Erwin et al., 1956a) fed fattening rations containing over 5 percent fat.

When the level of fat exceeds 5 percent in rations containing prairie hay or higher quality roughage nitrogen retention appears to be essentially unchanged (Hubbard, 1957). The digestibility of crude protein appears to parallel nitrogen retention but crude fiber and nitrogen-free extract digestibility is decreased significantly (Lucas and Loosli, 1944; Swift et al., 1947, 1948; Erwin et al., 1956b; Hubbard, 1957). Because of variable results, and the limited amount of information available, further work appears necessary to evaluate the effects of fat in a wintering-type ration based on prairie hay and a protein supplement. Also, advantage should be taken of recently developed techniques with the artificial rumen to study such interrelationships as fat and mineral (calcium and magnesium) metabolism in the ruminant. Such studies have recently been reported by Davison and Woods, 1959.

The Effect Of Carbohydrate On Nitrogen Retention and Nutrient Utilization

Previous Oklahoma Work

In nitrogen metabolism trials with steers fed wintering-type rations Fontenot (1953) obtained data indicating that increased energy intake in the form of concentrate feed exerts a protein-sparing effect. Two pounds of a feed supplement containing 20 percent protein resulted in a higher average nitrogen retention by beef steers than 1 lb of a supplement containing 40 percent protein, when each was fed with the same amount of prairie hay. However, the observations were made on a small number of animals, four receiving the 20-percent protein supplement and three receiving the 40-percent protein supplement.

In a series of three experiments with steers, Fontenot et al. (1955) determined the effect of adding increasing amounts of glucose to wintering rations containing approximately 8, 10 and 12 percent protein. The basal rations were composed of prairie hay, cottonseed meal and minerals in the proportions frequently fed to wintering beef cattle. Additions of 350, 700 and 1050 gm of glucose were made to the 8 percent ration and 700 and 1050 gm to the 10 and 12 percent rations. At each level of nitrogen intake provided by the three basal rations, the glucose supplements increased the amount of nitrogen in the feces and decreased the amount excreted in the urine. The magnitude and direction of these changes in nitrogen excretion were such that the net results of the glucose additions were (1) a significant decrease in nitrogen retention with the 8 percent protein basal ration, (2) a significant increase in nitrogen retention with 10 percent protein, and (3) a small although not significant increase with the 12 percent protein ration. The added glucose increased the estimated (Thomas-Mitchell) biological value of the nitrogen of all three basal rations. It decreased the apparent, but not the true, digestibility of protein, depressed the digestibility of crude fiber, and increased the amount of digestible nitrogen-free extract. It appears that in wintering rations, such as the one used in this experiment, the value of additional energy in the form of readily available carbohydrate to spare nitrogen in metabolism is nullified, in part, by the decreased digestibility of protein and crude fiber.

Hubbard (1957) conducted a balance trial in which the effect of added starch on nitrogen utilization and digestibility by steers was studied. In this trial, 440 gm of corn starch were added to a basal ration of 3000 gm prairie hay, 50 gm minerals (dicalcium phosphate and salt, 1:1), and

600 gm cottonseed meal; protein content of the ration was reduced from 11 to 10 percent by the addition. The starch addition decreased urinary nitrogen from 29.7 to 23.5 and increased fecal nitrogen from 25.2 to 27.4. Both of these values were significant; however, the decrease in urinary nitrogen was sufficiently larger than the increase in fecal nitrogen that the net result was a significant increase in nitrogen retention from 5.6 to 9.8 gm. The digestibility of crude protein and crude fiber was significantly decreased, and organic matter, dry matter and ether extract digestibility was not significantly altered. Thus, the advantage of increased nitrogen retention by starch was nullified in part by increased nitrogen wasted in digestion and decreased crude fiber digestibility.

Robinson (1958) studied the value of energy added as corn to wintering rations or prairie hay and cottonseed meal. The basal ration contained 3000 gm of prairie hay, 454 gm of cottonseed meal, 25 gm dicalcium phosphate and 25 gm salt. In these trials 118 gm of cottonseed meal was replaced with an iso-nitrogenous amount of corn (572 gm). The addition of corn decreased nitrogen excretion in the urine from 16.33 gm to 14.18 gm, but increased the nitrogen in the feces from 22.04 gm to 24.80 gm. The increased fecal nitrogen excretion was associated with the increased intake and excretion of dry matter and a significant drop in the digestibility of crude fiber. Total nitrogen retention was decreased from 24.2 percent of the intake to 22.5 percent. Crude protein digestibility was also significantly decreased. The substitution of corn for an iso-nitrogenous amount of cottonseed meal in a wintering ration of prairie hay and cottonseed meal resulted in a marked decrease in utilization of nitrogen in digestion which resulted in a decrease in nitrogen retention even though nitrogen was spared in metabolism.

Balance and Digestion Trials

Patterson and Outwater (1907) reported that molasses decreased the digestibility of dry matter in rations of hay or hay and grain fed to steers. Lindsay and Smith (1910) reported that molasses decreased organic matter digestibility in rations of hay or hay and concentrate fed to sheep. Molasses when fed with hay alone had to be present in relatively high concentrations to cause a marked depression. Williams (1924), working with dairy cows, reported that molasses did not uniformly affect the digestibility of crude fiber, nitrogen-free extract, and ether extract but tended to depress the digestibility of crude protein and dry matter.

Briggs (1937) found that the substitution of 230 gm of molasses for 224 gm of grain in a lamb fattening ration of alfalfa and grain, 1:1, decreased apparent digestibility of protein and fat and had no apparent effect on the digestibility of crude fiber and nitrogen-free extract. In later studies (Briggs and Heller, 1940) with a similar ration it was found that the substitution of molasses for either corn or oats had no appreciable effect on the apparent digestibility of crude fiber and nitrogen-free extract. The substitution of molasses for corn had no significant influence on the apparent digestibility of crude protein but the replacement of oats with molasses lowered crude protein digestibility by a highly significant amount.

Mitchell *et al*. (1940) conducted an experiment with beef calves to study the effect of glucose on nitrogen retention and digestibility of crude fiber. The plan of the experiment involved the testing of four experimental rations consisting essentially of timothy hay, corn and cottonseed meal in various combinations to provide the four rations with different percentages of crude protein. Four steers were fed each of the four rations containing 7.53, 9.94, 15.57 and 22.41 percent protein alone and supplemented with glucose. Steers fed the three highest protein rations consumed 1000-1200 gm glucose. Three steers fed 7.53 percent protein rations consumed 400 gm glucose and one consumed 100 gm. The average daily nitrogen balances, expressed in grams, for the rations of different protein content with and without glucose, respectively, were: 7.53 percent protein, 5.39 and 5.65; 9.94 percent protein, 8.81 and 10.38; 15.57 percent protein, 21.81 and 15.52; 22.41 percent protein, 23.22 and 19.22. Thus, the protein-sparing effect of the sugar supplement was evident only when glucose was added to basal rations containing about 10 percent or more protein. Digestibility was determined only on crude fiber and it was decreased an average of 25 percent.

Hamilton (1942) studied the effect of added glucose on the digestibility of ration constitutents by sheep. The basal ration contained cut timothy hay, ground yellow corn and cottonseed meal in approximate ratios of 2:2:1 and analyzed 14.6 percent protein. The animals were fed 1.64 lbs of basal ration per 100 lbs live-weight. When sugar was fed, the animals received, in addition to the basal ration, 150 to 200 gm of corn sugar daily. In addition, in each period each sheep received 6 gm bonemeal, 3 gm salt, 3 gm yeast and 0.5 cc cod liver oil. The plan of feeding was a double reversal procedure. The average apparent digestion coefficients for the basal ration and the basal ration plus sugar, respectively, were: dry matter, 65.4 and 67.7 percent; total nitrogen, 61.9 and 54.1 percent; crude fiber, 43.8 and 31.9 percent; and nitrogen-free extract, 76.4 and 79.7 percent. The addition of the sugar caused a significant decrease in apparent crude protein and crude fiber digestibility and a significant increase in the apparent digestibility of nitrogen-free extract. It was concluded that the decrease in protein digestibility was due to an increase in metabolic nitrogen resulting from increased intake of dry matter (sugar). The decrease in fiber digestibility was thought to be due to the rumen cellulolytic microorganisms preference of sugar to fiber.

Swift et al. (1947) reported on the influence of starch and cerelose on the digestibility of rations by sheep. A 13.2 percent protein ration composed of 420 gm mixed hay (alfalfa and timothy of excellent quality), 420 gm corn meal and 48 gm linseed oil meal was supplemented with 58 and 116 gm of glucose and with the same amounts of starch. The sheep refused to eat the larger amount of starch so results were obtained with only the smaller one. The addition of 58 gm of glucose resulted in a significant increase in the digestibility of dry matter and energy of the ration but had no significant effect on the apparent digestibility of crude protein. The addition of 116 gm of glucose caused a significant decrease in the apparent digestibility of crude protein and crude fiber. No appreciable change in the digestion coefficients of total dry matter and energy was produced. The feeding of 58 gm of starch per day caused a depression in the apparent digestibility of crude protein and crude fiber. These workers concluded that this experiment gave evidence that the amount of a supplement added may determine whether its effect will be beneficial or detrimental. The explanation for decreased digestibility resulting from the addition of the high level of glucose and the low level of starch was quoted from Hamilton (1942).

In an experiment with dairy calves, Colovos et al. (1949) found that the addition of either wood or cane molasses to a grass-legume hay ration caused a decrease in the average apparent digestibility of crude protein.

The addition of wood molasses was accompanied by a decrease in urinary nitrogen, an increase in fecal nitrogen and a small increase in average nitrogen balance. Cane molasses appeared less effective in reducing the urinary nitrogen.

Burroughs et al. (1949) conducted five series of digestion trials to study the effect of mineralized corn starch on the digestibility of roughage dry matter by steers. They found that if corncobs or corncobs and a limited amount of alfalfa hay made up the roughage part of the ration, the addition of corn starch caused a marked reduction in the digestibility of the roughage dry matter. However, if alfalfa hay was the only source of roughage the corn starch had no such consistent effect. "This difference can best be reconciled on the basis that alfalfa hay contained more essential nutrients than corncobs for promoting growth of microorganisms. The larger stores of nutrients in alfalfa hay were sufficient to withstand starch fermentation and still have enough food essentials to promote growth of roughage digesting microorganisms. Conversely the smaller stores of nutrients in corncobs were insufficient to maintain the microorganisms capable of digesting roughage, following the earlier utilization of essential nutrients in starch fermentation."

Lofgreen et al. (1951) studied the influence of energy intake on nitrogen retention in growing dairy calves. Eighteen Holstein heifer calves weighing about 150 lbs. each were divided into four lots and placed on four dietary treatments. The treatments were low energy-low protein, high energy-low protein, low energy-high protein and high energy-high protein rations. The low protein level was the crude protein allowance as recommended by the Morrison standard and the high protein was 160 percent of this allowance. The low-energy level was the total digestible nutrient allowance recommended by the Morrison standard and the high-energy level was 115 percent of the allowance. The hay used was good quality alfalfa, timothy, or clover hay. The concentrate mixture was a 16 percent protein commercial calf starter at the start of the experiment and was changed to a growing mixture when the animals reached about 250 lbs. The proper proportions of protein were maintained by supplementing the starter or growing mixture with a mixture of protein supplements. To furnish the high energy level, the total feed allowance was increased while maintaining the protein intake constant by the proper reduction in the percentage of protein in the concentrate mixture. Nitrogen balances were determined when the calves weighed 150, 200, 250 and 300 lbs. The average nitrogen retention, expressed as the percent of consumed nitrogen was 25.8 and 31.6 gm, respectively, for the animals fed low energy-low protein and high energy-low protein rations, and 24.4 and 21.5 gm respectively, for those fed the low energy-high protein and high energy-high protein rations. Increasing the non-nitrogenous total digestible nutrient consumption resulted in a marked increase in nitrogen retention of dairy calves fed at a low protein level but was without effect if the calves were fed at a high protein level. The authors concluded that on a low protein intake an increase in non-nitrogenous total digestible nutrients consumption resulted in a marked increase in the retention of the nitrogen available for growth.

Chappel (1952) studied the effect of readily available carbohydrate on the digestibility of a ration of prairie hay and casein fed to lambs. The basal ration contained 600 gm prairie hay and 60 gm casein. The experimental rations were the basal plus 60 or 180 gm of glucose. The addition of glucose to the basal ration had no measurable effect on the apparent coefficient of digestibility of crude fiber of the ration. The average apparent percentage of crude fiber digested was 57.3, 56.6 and 57.0 for rations containing 0, 60 and 180 gm of glucose, respectively. The apparent coefficient of digestibility for crude protein was significantly decreased when the higher level of cerelose was fed but was not significantly altered when the lower level was fed. The average percentage of crude protein digested was 67.9, 68.7 and 63.5, respectively, for the rations containing 0, 60 and 180 gm of glucose. From the results obtained in this experiment it would appear that the addition of a small quantity of readily available carbohydrate had very little effect on the utilization of a low quality roughage ration by lambs as measured by the apparent percentage of digestibility of the crude fiber and crude protein contained in this ration.

Williams <u>et al</u>. (1953) studied the effect of adding two levels of starch to low energy rations of different protein content on nitrogen utilization by sheep. Wheat starch and wheat gluten were added to a basal ration of oat chaff to furnish different energy and protein contents. They found that the addition of 49 or 99 gm of starch to 270 gm of a basal ration containing 5.2 percent protein resulted in a significant increase in the estimated (Thomas-Mitchell) biological value of the protein. Nitrogen retention data were not given but urinary nitrogen was significantly decreased. However, the addition of either level of starch to basal rations containing 10.0 or 13.1 percent protein produced no significant effect on the estimated (Thomas-Mitchell) biological value of the protein. Four animals per treatment were used. The authors concluded that the high levels of protein feeding exceeded the maximum required for the full utilization of the absorbed nitrogen.

Summers <u>et al</u>. (1956) found that a decrease in the corncob content of a ration from 80 to 65 percent by corn starch replacement significantly reduced the digestibility of cellulose from 74.2 to 68.4 percent. Alfalfa ash (30 gm per wether per day) prevented this effect of the supplemental corn starch but had no effect on the digestibility of the basal ration containing 80 percent corncobs. Thus the depressing effect that starch had on cellulose digestion in this experiment could be reversed by alfalfa ash.

Woods et al. (1956) studied the effect of varying levels of protein and glucose on the utilization of mature timothy hay by sheep. They found that as the percentage protein increased from 6.9 to 10.9 to 13.6 the apparent digestibility of dry matter, organic matter, protein, energy and nitrogen-free extract increased. The addition of either 3.3 or 6.2 percent glucose at all levels of protein had no significant effect on the digestibility of dry matter, organic matter and energy. However, with each glucose addition the digestibility of nitrogen-free extract was increased significantly. The addition of 3.3 percent glucose at all levels of protein had no significant effect on the digestibility of protein, but the additional 6.2 percent of glucose significantly decreased protein digestibility below that of rations containing 0 and 3.3 percent of glucose. The authors concluded that the ration was deficient in protein. The decrease in protein digestibility obtained when the higher level of glucose was added was thought to be due to increased metabolic nitrogen.

From the literature reviewed it appears that for a carbohydrate supplement to effect a measurable saving of protein the initial level of protein and the total energy content of the supplemented ration must be above certain prescribed levels (Mitchell et al., 1940; Lofgreen et al., 1951; Fontenot et al., 1955). The effect of an addition of a readily-available carbohydrate on digestibility appears to be dependent on the amount added. Small quantities appear to either increase or have no measurable effect on digestibility except for increasing nitrogen-free extract digestibility (Swift _et al._, 1947; Arias _et al._, 1951; Chappel, 1952; Woods _et al._, 1956). Large quantities usually decrease digestibility of all ration constituents except nitrogen-free extract (Mitchell _et al._, 1940; Swift _et al._, 1947; Fontenot _et al._, 1955; Hubbard, 1957; Robinson, 1958). Alfalfa ash has been found to reverse the effect of large quantities of added carbohydrate on digestibility (Summers _et al._, 1956) and the quality of roughage may determine the effect that carbohydrate additions have on digestibility (Burroughs _et al._, 1948). Because of the variable results of the experiments cited further work is necessary to evaluate different energy sources and determine their effect in a wintering-type ration based on prairie hay and a protein supplement. Different sources of energy, carbohydrate and fat should be compared within the same trial to eliminate some sources of error and variation common to balance and digestibility trials with large animals.

EFFECT OF ADDED FAT AND CARBOHYDRATE ON DIGESTIBILITY OF RATION NUTRIENTS AND NITROGEN METABOLISM

EXPERIMENT I

The purpose of this experiment was to determine the effect of added fat (corn oil) at a level of 10.4 percent on nitrogen utilization, digestibility of nutrients and calcium retention by steers fed a high protein wintering-type ration. In a previous experiment (Hubbard, 1957) 10 percent corn oil was added to a wintering-type ration composed of 3000 gm prairie hay, 585 gm cottonseed meal, 323 gm corn, 25 gm salt and 25 gm dicalcium phosphate. Corn was included to improve the physical nature of the supplemented ration. Sufficient cottonseed meal was used to provide approximately 10 percent protein in the supplemented ration. The amounts of corn and cottonseed meal in the basal ration may have supplied enough energy to mask the effect of additional energy in the form of corn oil. Therefore, in the present study, Drackett protein* was used to increase the percentage of protein without increasing appreciably the energy content of the ration. It was also desired to note the effect of corn oil at a higher protein level.

Experimental Procedure

Twelve grade Hereford steers weighing about 625 lb. at the start of the experiment were used in two digestion trial periods extending from

*Drackett protein is an assay protein produced from soybean oil meal and contains 88.5 percent protein (N x 6.25) on a dry-matter basis. It is manufactured by the Drackett Products Company, 5020 Spring Grove Avenue, Cincinnati 32, Ohio.

January 22, 1958, to March 29, 1958. A completely randomized design was used to allot the steers to two rations, basal and supplemented. The steers were kept in metabolism stalls as described by Nelson et al. (1954).

The basal ration consisted of 3000 gm prairie hay, 350 gm Drackett protein, 454 gm cottonseed meal, 25 gm dicalcium phosphate, and 25 gm salt. The supplemented ration was the basal ration plus 400 gm corn oil. The corn oil addition lowered the protein content in the ration from 17.1 to 15.4 percent.

The rations and the chemical composition of the feeds are shown in Table 1. The average chemical composition of the basal and supplemented rations is given in Table 2.

The prairie hay was of average quality. The cottonseed meal was manufactured by the expeller process. The oil was added to the concentrate mixture (454 gm cottonseed meal, 350 gm Drackett and minerals) and was gradually increased to 10.4 percent over a 10-day feeding period. A 10-day preliminary period preceded each 10-day collection period making a total of 30 days in each trial. The steers were fed one-half the daily allowance twice daily.

Feces were collected in metal boxes and transferred at frequent intervals to covered metal containers. The feces were weighed daily and 5 percent samples were preserved in tightly covered glass jars under refrigeration. Thymol crystals were used to aid in preservation. Proximate analyses, as described by the Association of Official Agricultural Chemists (1950), were made on a composite 10-day sample from each steer. The urine was collected by means of a metal grid and metal funnel. The urine was diluted with water to a constant weight daily, and an aliquot was acidified with HCl and stored under refrigeration. Nitrogen was determined by the

TABLE 1

Daily Allowances and Average Chemical Composition of Feeds in Experiment 1

	Daily Allowance in Ration			Percentage Composition of Dry Matter							
Feed	Basal	Basal + corn oil	Dry matter	Organic matter	Protein (N X 6.25)	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Nitrogen	Cal-cium
Prairie hay	3000	3000	93.2	93.0	4.89	2.6	32.3	53.2	7.0	0.8	0.4
Cottonseed meal	454	454	93.4	94.0	44.6	4.5	12.5	32.4	6.0	7.1	0.3
Drackett	350	350	92.2	97.3	89.0	0.2	0.1	8.0	2.6	14.2	0.6
Corn oil	0	400	100.0	100.0	--	100.0	--	--	--	--	--
Mineral	50	50	100.0	--	--	--	--	--	100.0	--	15.2

TABLE 2

Average Chemical Composition of Rations Eaten in Experiment 1

Ration	Daily amount fed	Percent dry matter	Percentage Composition of Dry Matter							
			Organic matter	Protein (N X 6.25)	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Nitrogen	Calcium
Basal	3854	93.3	92.2	17.1	2.6	26.7	46.0	7.8	2.7	.62
Basal + corn oil	4254	93.9	93.0	15.4	12.3	24.0	41.4	7.0	2.5	.56

Kjeldahl method on combined daily aliquots from each steer.

The Thomas-Mitchell formula was used in the calculation of biological value of the nitrogen: Biological value =

$$\frac{\text{N intake} - (\text{fecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic N})} \times 100$$

The metabolic nitrogen and endogenous nitrogen were calculated by the method proposed by Swanson and Herman (1943). Fecal metabolic nitrogen was considered to be 5.3 gm per kilogram of dry matter intake. In calculating the endogenous urinary nitrogen the following equation was used: $N = 0.712\ W^{0.42}$ where N represents the grams of endogenous nitrogen and W the body weight in kilograms. Swanson and Herman calculated these values from results obtained by feeding low-nitrogen rations to dairy heifers.

The results of this experiment were analyzed statistically by the analysis of variance procedure as described by Snedecor (1956).

Results and Discussion

The average daily nitrogen balance and biological value data are given in Table 3. The individual data for nitrogen balance and biological value are presented in Table I, appendix.

The addition of 400 gm of corn oil to the concentrate portion of the ration resulted in a very oily mixture. When this mixture was fed without any adjustment period consumption was unsatisfactory; however, if the oil was increased by 40 gm per day over a 10-day period the steers adjusted to it gradually and consumption was very satisfactory. The oil feeding resulted in slight constipation.

The corn oil added to the basal ration decreased urinary nitrogen from 52.9 to 52.2 gm and increased fecal nitrogen from 29.3 to 29.9 gm.

TABLE 3

Average Daily Nitrogen Balance and Biological Value Data in Experiment 1

Ration	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention[a]		Metabolic N[b]	Endogenous N[c]	True digested N[d]	Absorbed N utilized[e]	Biological value[f]
	gm	gm	gm	gm	gm	%	gm	gm	gm	gm	%
Basal	3594.5	98.0	29.3	52.9	15.8	16.1	19.1	7.56	87.8	42.4	48.3
Basal + corn oil	3994.5	98.0	29.9	52.2	15.9	16.2	21.2	7.56	89.3	44.7	50.0

a/ Total ration nitrogen minus urinary and fecal nitrogen.
b/ 5.3 gm/kg dry matter intake.
c/ $N = 0.712\ W^{0.42}$ where N represents the grams of endogenous urinary nitrogen and W the body weight in kilograms.
d/ N intake - (fecal N - metabolic N).
e/ N intake - (fecal N - metabolic N) - (urinary N - endogenous N).
f/ $\dfrac{\text{N intake} - (\text{fecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic N})}$

Neither of these changes was statistically significant; in fact, the changes were too small to affect nitrogen retention. Average daily nitrogen retention was 15.8 and 15.9 gm for the basal and corn oil rations, respectively. The increase in fecal nitrogen was associated with increased intake and excretion of dry matter and a significant decrease in the digestibility of crude fiber. However, feed nitrogen excretion in the feces was greater on the basal ration than on the supplemented ration if correction is made for metabolic nitrogen on the basis of 5.3 gm per kg dry matter intake. Hubbard (1957) has previously found that 10 percent corn oil added to a similar wintering-type ration containing 11 percent protein did not significantly affect nitrogen retention. However, Robinson (1958) fed 5 percent corn oil in a wintering-type ration containing 10 percent protein and obtained a significant increase in nitrogen retention. In experiments where cottonseed hulls or corn cobs served as the roughage, nitrogen retention has been found to be significantly decreased by the addition of 3 to 10 percent corn oil to rations for cattle and sheep (Rhodes _et_ _al_., 1947; Summers _et_ _al_., 1956; Ward _et_ _al_., 1957).

The corn oil increased the estimated biological value of nitrogen but not significantly. Average values for the basal and supplemented ration were 48.3 and 50.0, respectively. Mitchell (1924) observed that a decrease in the protein percentage of a ration (wide nutritive ratio) such as occurred in the corn oil ration is usually accompanied by an increase in biological value of nitrogen. Robinson (1958) obtained a significant increase in biological value when he added 5 percent corn oil to a similar ration. Nevertheless, in the present experiment the addition of 10.4 percent corn oil to a basal wintering ration containing 17.1 percent protein had little, if any, effect in sparing nitrogen. Also, Hubbard (1957) failed to produce a nitrogen-sparing effect by adding 10 percent corn oil to a basal wintering ration containing 11 percent protein and having a higher energy: protein ratio.

Average values for apparent digestibility of nutrients along with fecal ash and calcium data obtained with the basal and supplemented rations are shown in Table 4. The individual values are given in Table II in the appendix. The corn oil decreased all the digestion coefficients except that for ether extract, which increased significantly ($P < 0.01$) from 55.4 to 80.9. This is in agreement with Swift et al. (1947) who observed that when a ration containing 8 percent corn oil was fed it decreased all digestion coefficients except ether extract. Many workers have observed an increase in the digestion coefficient of ether extract when high levels of fat are fed to ruminants. However, these estimates of ether extract digestibility may be more apparent than real. It has been postulated that fat feeding increases excretion of soaps which are mineral salts of fatty acids. If this were the case, these soaps would be present in the nitrogen-free extract fraction thus causing an over estimate of ether extract digestibility and an under-estimate of nitrogen-free extract digestibility. Several workers (Brooks et al., 1954; Summers et al., 1956; Ward et al., 1957; Grainger et al., 1957; Brethour et al., 1958, White et al., 1958; Tillman and Brethour, 1958; and Davison and Woods, 1959) have stated that fat feeding increases mineral (alfalfa ash or calcium) requirement.

The digestibility of crude fiber was decreased ($P < 0.01$) from 67.1 percent to 50.1 percent by the addition of corn oil. This result which agrees with those obtained by other workers (Lucas and Loosli, 1944; Swift et al., 1948; Hubbard, 1957; Ward et al., 1957; Grainger et al., 1957; Robinson, 1958; White et al., 1958; and Davison and Woods, 1959)

TABLE 4

Digestibility Data Obtained with Steers Fed the Basal and Supplemented Ration in Experiment 1

Ration	Corn oil intake	Fecal ash	Calcium excretion	Dry matter	Organic matter	Protein (N X 6.25)	Ether extract	Crude fiber	Nitrogen - free extract	T.D.N.
		gm	gm							%
				Apparent Digestibility, Percent						
Basal	0	190.9	17.1	62.4	65.0	71.1	55.4	67.1	62.5	61.8
Basal + corn oil	400	198.7	17.3	55.2	57.2	69.5	80.9	50.1	49.7	65.6
				Apparent Digestibility, Grams						Gms
Basal	0			2244.0	2156.0	430.0	51.1	642.9	1032.9	2220.7
Basal + corn oil	400			2205.5	2125.3	426.3	398.6	479.5	820.5	2621.6

may have been affected in part by the decreased protein percentage of the supplemented ration.

The average digestibility of protein was decreased from 71.1 percent in the basal to 69.5 in the supplemented ration. This small decrease was not statistically significant at the 5 percent level, but it is in agreement with the findings of Robinson (1958) and Hubbard (1957) and other investigators who have added corn oil to high roughage rations for cattle (Lucas and Loosli, 1944) and sheep (Swift et al., 1948).

The average digestibility of nitrogen-free extract was reduced from 62.5 percent to 59.7 percent. This observation that fat addition decreases the digestibility of nitrogen-free extract is in agreement with the reports of Lucas and Loosli (1944), Swift et al. (1947, 1948), Ward et al. (1957), Hubbard (1957) and Robinson (1958).

The digestion coefficients for dry matter and organic matter followed similar patterns. Both were significantly decreased ($P < 0.01$) by the corn oil. The average digestion coefficients for the basal and supplemented rations were 62.4 and 55.2 percent, respectively, for dry matter and 65.0 and 57.2, respectively, for organic matter. This has been a general observation by most all workers who have added fat to ruminant rations.

The corn oil significantly ($P < 0.05$) increased the excretion of minerals (ash) in the feces from 190.9 gm to 198.7 gm per day. Thus, it could be postulated that this level of fat increases the requirement for certain minerals for efficient digestion of crude fiber and nitrogen-free extract. Davison and Woods (1959) noted a significant increase in fecal ash when corn oil was fed. Also, they reported that calcium carbonate largely overcame the depressing effect of corn oil on digestibility. Grainger et al.

(1957) and White et al. (1958), on the basis of results of digestibility trials in which fat was added to a semi-purified diet, commented that 5 percent corn oil increased the calcium requirement of sheep. Tillman and Brethour (1958) noted that 7.5 percent corn oil did not affect fecal endogenous or urinary excretion of dietary calcium, but significantly decreased the retention of dietary calcium which closely paralleled increased fecal excretion of calcium. However, in the present experiment calcium excretion by the animals receiving fat was only slightly increased, 17.1 vs. 17.3 gm per day. The results of this experiment do not appear to be in agreement with the findings of Tillman and Brethour; however, the two experiments were conducted under such different conditions that they are not strictly comparable. From the results of the present experiment, calcium appears to comprise only a very small proportion of the increase in mineral excretion.

EXPERIMENT 2

The purpose of this experiment was to compare the effects of added corn oil, glucose and starch on nitrogen utilization, calcium retention and digestibility of nutrients by steers fed a wintering-type ration containing 10 to 11 percent protein. The plan was to use these supplements in such amounts that their addition to the basal ration would make an effective increase in energy and only a small change in percentage of protein. An increase in feed intake with nitrogen intake kept constant and at a low level has been shown to increase nitrogen retention by growing dairy calves (Lofgreen et al., 1951).

Experimental Procedure

A group of eight Hereford steers weighing between 475 and 590 lb. was used in a series of four nitrogen balance trials extending from December 6, 1958, to May 20, 1959. In each trial the eight steers were fed a constant daily amount of a basal and three supplemented rations, two steers being fed each ration. The experiment was of a completely randomized design with the restriction that no animal would be fed any one ration more than once.

The basal wintering-type ration contained 3000 gm prairie hay, 500 gm cottonseed meal, 25 gm salt and 25 gm dicalcium phosphate. Its average protein content was 11.1 percent (dry matter basis). The three supplemented rations contained in addition 200 gm of one of the following supplements: glucose (Cerelose), corn starch and corn oil. These additions lowered the protein content of the supplemented rations to 10.5 percent. The steers were fed one-half the daily allowance twice daily. There were no feed refusals.

The feeds used were similar in quality to those described for Experiment 1. Their chemical composition is given in Table 5. The average chemical composition of the rations is shown in Table 6.

The steers were handled in a similar manner as in Experiment 1, except that they were removed from the metabolism stalls and placed on pasture for two weeks between trials 2 and 3. The methods used in collecting, sampling, and analyzing the excreta, and in the treatment of data, were similar to those described for Experiment 1.

Results and Discussion

Average nitrogen balance and biological value data are given in Table 7; the individual data are presented in Table III, appendix.

TABLE 5

Daily Amounts and Average Chemical Composition
of Feeds in Experiment 2

	Daily Allowance in Ration, gm				Per-	Percentage Composition of Dry Matter							
Feed	Basal	Basal + Cerelose	Basal + Starch	Basal + corn oil	cent dry matter	Organic matter	Protein (N X 6.25)	Ether ex-tract	Crude fiber	Nitrogen-free extract	Ash	Nitro-gen	Cal-cium
Prairie hay	3000	3000	3000	3000	93.6	93.5	5.7	2.2	33.5	52.2	6.5	0.9	0.4
Cottonseed meal	500	500	500	500	93.6	93.1	44.5	4.6	12.5	31.5	6.9	7.1	0.4
Cerelose (glucose)	--	200	--	--	100.0	100.0	--	--	--	100.0	--	--	--
Starch	--	--	200	--	100.0	100.0	--	--	--	100.0	--	--	--
Corn oil	--	--	--	200	100.0	100.0	--	100.0	--	--	--	--	--
Mineral[a/]	50	50	50	50	100.0	--	--	--	--	--	100.0	--	15.2

a/ Dicalcium phosphate and salt (1:1 ratio).

TABLE 6

Average Chemical Composition of Rations Eaten in Experiment 2

Ration	Daily amount fed	Percent dry matter	Percentage Composition of Dry Matter							
			Organic matter	Protein (N X 6.25)	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Nitrogen	Calcium
Basal	3550	93.7	92.0	11.1	2.5	30.0	48.5	8.0	1.8	0.6
Basal + cerelose	3750	94.0	92.5	10.5	2.3	28.3	51.4	7.5	1.7	0.6
Basal + starch	3750	94.0	92.5	10.5	2.3	28.3	51.4	7.5	1.7	0.6
Basal + corn oil	3750	94.0	92.5	10.5	8.0	28.3	45.7	7.5	1.7	0.6

TABLE 7

Average Daily Nitrogen Balance and Biological Value
Data in Experiment 2

Ration	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention[a]		Metabolic N[b]	Endogenous N[c]	True digested N[d]	Absorbed N utilized[e]	Biological value[f]
	gm	gm	gm	gm	gm	%	gm	gm	gm	gm	%
Basal	3326.4	59.0	26.3	22.5	10.2	16.8	17.6	7.1	50.4	35.0	68.8
Basal + cerelose	3526.4	59.0	26.3	21.3	11.5	18.9	18.7	7.1	51.5	37.3	72.1
Basal + starch	3526.4	59.0	25.5	21.4	12.1	20.0	18.7	7.1	52.2	37.4	71.4
Basal + corn oil	3526.4	59.0	26.5	19.5	13.1	21.4	18.7	7.1	51.3	38.8	75.3

a/ Total ration nitrogen minus urinary and fecal nitrogen.
b/ 5.3 gm/kg dry matter intake.
c/ $N = 0.712\ W^{0.42}$ where N represents the grams of endogenous urinary nitrogen and W the body weight in kilograms.
d/ N intake - (fecal N - metabolic N).
e/ N intake - (fecal N - metabolic N) - (urinary N - endogenous N)
f/ $\frac{\text{N intake} - (\text{fecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic N})} \times 100$

The average amount of nitrogen retained by the steers fed the basal ration and the basal plus 200 gm glucose, starch and corn oil was 10.2, 11.5, 12.1 and 13.1 gm, respectively. The increases in average nitrogen retention obtained with the rations supplemented with glucose and starch were not statistically significant. They were associated with decreases in urinary nitrogen; and, in the case of the starch addition, the increase was associated with a decrease in fecal nitrogen.

In other experiments glucose in large amounts, 20 percent or more, increased significantly the retention of nitrogen (Fontenot *et al.*, 1955), and starch in relatively large amounts, 10 percent, also significantly increased nitrogen retention (Hubbard, 1957). In both cases fecal nitrogen was significantly increased; however, the efficiency of utilization of absorbed nitrogen (decreased urinary nitrogen) was increased to the extent that a protein-sparing action was effected. The difference between those results appears to be due to the difference in amount of added supplement which in turn affects both nitrogen digestibility and nitrogen metabolism.

The increase in nitrogen retention obtained with corn oil expressed as grams per day or percent of intake was significant ($P < 0.05$). Urinary nitrogen was decreased from 22.5 to 19.5; fecal nitrogen was essentially unchanged. This is in agreement with Robinson (1958) who also added 5 percent (200 gm) corn oil in a basal wintering-type ration of prairie hay and cottonseed meal. In his experiment, urinary nitrogen was decreased from 17.45 to 15.45 gm and fecal nitrogen was essentially unchanged. The finding that corn oil increased nitrogen retention is not in agreement with Experiment 1 or a previous experiment by Hubbard (1957) in which 10 percent corn oil was added to a wintering-type ration of prairie hay and cottonseed meal. In those experiments urinary nitrogen was decreased and fecal nitrogen was increased, although not to such an extent as to make a significant increase in nitrogen retention.

The addition of each of the three energy supplements appeared to increase the biological value of the nitrogen in the ration but none of these increaseswere statistically significant. The average biological values for the basal, glucose, starch and corn oil rations were 68.8, 72.1, 71.4 and 75.3, respectively. These results are in agreement with those reported by Fontenot et al. (1955), Hubbard (1957) and Robinson (1958).

It appears from these results that small amounts of fat are able to increase nitrogen retention by a decrease in urinary nitrogen excretion without producing a corresponding increase in fecal nitrogen whereas large amounts of fat, although decreasing urinary nitrogen excretion, produce an increase in fecal nitrogen and lowered digestibility of all ration nutrients except possibly ether extract. Carbohydrates, on the other hand, increase nitrogen retention only when added in relatively large amounts to produce a disproportionate change in urinary and fecal nitrogen excretion.

The average apparent digestion coefficients are given in Table 8. The individual results are presented in Table IV, appendix.

The average digestibility of organic matter in the basal ration alone and supplemented with glucose, starch and corn oil was 62.5, 66.0, 65.8 and 62.3 percent, respectively. Differences between the basal and carbohydrate supplemented rations were significant ($P < 0.01$). Dry matter digestibility followed a similar pattern, coefficients for rations in the above order being 59.9, 63.3, 63.1 and 60.0, respectively. The results with carbohydrate are in agreement with the work of Swift et al. (1947)

TABLE 8

Digestibility Data Obtained with Steers Fed the Basal and Supplemented Ration in Experiment 2

Ration	Carbohydrate or fat intake: Cerelose	Starch	Corn oil	Fecal ash	Fecal calcium	Dry matter	Organic matter	Protein (N X 6.25)	Ether extract	Crude fiber	Nitrogen-free extract	T.D.N.
	gm	gm	gm	gm	gm	Apparent Digestibility, Percent						
Basal	--	--	--	186.5	15.2	59.9	62.5	55.4	50.7	64.7	63.2	59.1
Basal + cerelose	200	--	--	183.1		63.3	66.0	55.4	50.7	66.3	68.5	62.5
Basal + starch	--	200	--	177.7		63.1	65.8	56.7	51.5	65.4	68.3	62.2
Basal + corn oil	--	--	200	179.4	14.5	60.0	62.3	54.8	80.6	61.9	61.2	65.8
						Apparent Digestibility, Grams						
Basal						1991.4	1913.3	205.1	41.8	646.9	1019.5	1965.5
Basal + cerelose						2232.9	2151.2	205.0	42.2	662.4	1241.5	2203.9
Basal + starch						2209.0	2147.0	207.8	42.6	652.7	1237.0	2195.3
Basal + corn oil						2116.7	2030.7	202.9	227.7	618.5	985.6	2319.3

who have noted that levels of readily-available carbohydrate similar to those used in this experiment increase the digestibility of organic matter, dry matter and energy. Other workers (Hamilton, 1947; Williams et al., 1953; Fontenot et al., 1955; Woods et al., 1956) have reported that a readily-available carbohydrate either decreased or produced no change in total dry matter digestibility. The results with corn oil are in general agreement with those of Robinson (1958).

The addition of 200 gm of starch significantly increased the apparent digestibility of protein from 55.4 to 56.7 percent; 200 gm of glucose resulted in no change and 200 gm of corn oil decreased it to 54.8 which is not significant. The increase in protein digestibility due to the addition of starch is not supported by the literature; however, the effects of this level of starch on a wintering-type ration such as the one used in this experiment has not previously been reported. The increase was small, indeed. Thus, further investigation appears to be warranted to confirm these results and provide a reasonable interpretation. Chappel (1952) feeding prairie hay as a roughage and Swift (1947) feeding mixed alfalfa and timothy hay noted that addition of 6 to 8 percent glucose had no significant effect on crude protein digestibility. The slight decrease in protein digestibility provided by corn oil agrees with the results of Experiment 1 and other work at this Station (Hubbard 1957; Robinson, 1958).

The average crude fiber digestibilities were 64.7, 66.3, 65.4 and 61.9, respectively, for the basal, glucose, starch and corn oil rations. In the case of the carbohydrate additions the changes in digestibility were not significant; however, corn oil significantly ($P < 0.05$) reduced crude fiber digestibility. The decrease due to the fat addition is in agreement with most all reports in the literature and the results of

Experiment 1. The finding that low levels of glucose had no significant effect on crude fiber digestibility is in agreement with the reports of Chappel (1952) and Woods et al. (1956); however, the literature does not support the findings with starch. Swift et al. (1947) reported that 6.5 percent starch added to a ration of 420 gm mixed hay, 420 gm corn meal and 48 gm linseed meal depressed digestibility of crude fiber.

The digestibility of nitrogen-free extract was significantly higher in the carbohydrate-supplemented rations than in the basal due very likely to the high digestibility of the supplements themselves. The addition of fat, in contrast to carbohydrate, significantly ($P < 0.01$) decreased nitrogen-free extract digestibility. These results are in general agreement with the literature cited.

As would be expected, the digestibility of ether extract was high in the fat-supplemented ration, (80.6 percent vs. 50.7 percent) and essentially unchanged in the carbohydrate-supplemented rations. The digestion coefficients for the basal ration and rations containing glucose, starch and corn oil were 50.7, 50.7, 51.5 and 80.6, respectively.

Excretion of minerals (ash) in the feces was reduced from 186.5 gm on the basal ration to 183.1 gm by glucose to 177.7 gm by starch, and to 179.4 gm by corn oil. This is in contrast to an increase in fecal ash obtained when either 10 percent corn oil or 10 percent starch was fed by Hubbard (1957). Davison and Woods (1959) reported an increase in fecal ash when approximately 5 percent corn oil was fed. Summers et al. (1956) claimed that 5 percent starch increased the rumen requirement for one or more inorganic elements in alfalfa ash.

Calcium excretion in the feces of the animals fed corn oil followed a pattern similar to ash; it decreased from 15.2 to 14.5 gm. This finding is not in agreement with other workers (Grainger et al., 1957; White et al., 1958; Tillman and Brethour, 1958; Davison and Woods, 1959).

EXPERIMENT 3

The purpose of this experiment was to study the effect of addition of calcium, magnesium or iron to a fermentation media of rumen fluid collected from steers fed 10 percent corn oil in a wintering type ration of prairie hay and cottonseed meal.

Experimental Procedure

Four fistulated Angus steers, two sets of identical twins, were fed a wintering-type ration containing 900 gm cottonseed meal and 5500 gm prairie hay. One steer in each pair was fed 700 gm of corn oil in addition. The steers were individually-fed the above rations in two equal amounts daily. Salt was given free-choice.

The apparatus and procedure used for these in vitro studies were similar to those described by Cheng et al. (1955). Into each of 24 fifty milliliter centrifuge tubes 120 mg of cellulose (Solka floc) was weighed. These tubes were divided into four groups of six each. Six tubes were used as controls. The treatment groups were 2 mg additions of calcium carbonate, magnesium carbonate and ferric oxide. All minerals were reagent grade and weighings were made to the nearest 0.1 mg on a Mettler electronic balance.

In four trials rumen fluid samples were alternately collected from the twin sets approximately four hours after the morning feeding. These samples were taken through a permanent rumen fistula and strained through four layers of cheesecloth into thermos bottles which previously had been warmed to 40°C.

The samples were immediately taken to the laboratory where they were centrifugated for 5 minutes at 475 X g. After being centrifuged, the supernatant material was strained through four layers of cheesecloth and 25 ml of this material was added to each tube. One-half of the tubes in each treatment group were filled with rumen fluid from each steer.

After the rumen fluid had been added, the tubes were placed in a water bath set at 39°C. and CO_2 bubbled through the tubes for 48 hours. The purpose of the CO_2 was to maintain anaerobic conditions and also for agitation of the cellulose. After 48 hours the tubes were centrifuged at 600 X g for 10 minutes and the supernatant material was then poured off. Twelve ml of glacial acetic acid and 1.5 ml of concentrated nitric acid were added to each tube. The tubes were then placed in a boiling water bath for 20 minutes after which time they were removed, allowed to cool and then emptied into Gooch crucibles having asbestos in the bottom to prevent the cellulose from passing through. Each tube was washed with 95 percent ethyl alcohol and benzene to remove all cellulose and to act as a solvent for substances other than cellulose so that they may pass through the asbestos filter. The crucibles were dried at 100°C. for 24 hours, then cooled in a desiccator and weighed. After weighing they were ashed at 600°C. for 24 hours, cooled and reweighed.

Tubes used as "blanks" to determine cellulose digestion were selected prior to placing the other tubes in the water bath. One tube representing each treatment for each animal was centrifuged for 10 minutes at 3000 r.p.m., the supernatant liquid was poured off and 12 ml of glacial acetic acid was added. They were covered and left in the open for the 48 hour period corresponding to the time the other tubes were in the water bath, and then handled in the same manner as the other tubes.

Results and Discussion

The average cellulose digestion for all trials is given in Table 9. The individual trial data are presented in Table VI, appendix.

A highly significant ($P < 0.01$) difference in cellulose digestion was found when rations containing corn oil were compared to rations containing no corn oil. Ten percent corn oil in the diet was found to reduce *in vitro* cellulose digestion from 76.8 to 20.7 percent. This is in agreement with the findings of Davison and Woods (1959) who have noted a decrease in *in vitro* cellulose digestion due to corn oil. It is also in agreement with the numerous workers who have noted a decrease in *in vivo* crude fiber digestion due to corn oil feeding.

The addition of all three mineral sources to the rumen liquor from steers receiving 10 percent dietary fat increased cellulose digestion. The respective coefficients for the control sample and 2 mg ferric oxide, calcium carbonate and magnesium carbonate were 20.7, 23.3, 40.5 and 28.8 percent, respectively. In the case of the iron addition the difference was significant at the 5 percent level of probability; and in the case of the calcium and magnesium additions differences were significant at the 1 percent level. The latter finding is in agreement with Davison and Woods (1959), who found that magnesium carbonate and calcium carbonate were equally effective in partially alleviating the depressing effects of corn oil upon cellulose digestion *in vitro*.

Thus, it appears that corn oil increases the mineral requirement for

TABLE 9

Average Cellulose Digestion Obtained From Artificial Rumen Studies in Experiment 3

Treatment	Cellulose Digestion, %		No. of tubes per treatment
	Basal	Basal + corn oil	
Cellulose	76.8	20.7	8
Cellulose + iron	66.0	23.3	8
Cellulose + calcium	73.7	40.5	8
Cellulose + magnesium	74.7	28.8	8

rumen microorganisms. However, more than one mineral is apparently involved as has been previously implied in Experiment 1. If the alleviating effect of the minerals used in this study was additive then the addition of these three minerals to a diet such as the one used in this experiment would greatly improve cellulose digestibility.

The addition of ferric oxide to the rumen liquor of calves receiving no added fat in their diet significantly ($P < 0.01$) reduced cellulose digestion. However, the other two mineral additions had no significant effect. Hubbert *et al.* (1958) found that artificial rumen media containing no added iron supported higher cellulose digestion than that containing iron, and high levels of iron became extremely toxic.

SUMMARY

Digestion and nitrogen balance trials were conducted to compare the effect of energy supplements on nitrogen utilization by steers fed a wintering-type ration containing 11 percent protein. Each of the supplements; glucose, starch and corn oil, added in an amount of 200 gm (5.6 percent) to a basal ration of prairie hay, 3000 gm; cottonseed meal, 500; salt, 25; and dicalcium phosphate, 25) tended to increase nitrogen retention. Only the increase obtained with corn oil was statistically significant ($P \leq 0.05$). However, when 400 gm (10.4 percent) of corn oil was added to a similar wintering-type ration containing 17 percent protein (350 gm Drackett protein and 454 gm cottonseed meal as supplement to the hay) nitrogen retention was essentially unchanged. This large amount of oil impaired digestion.

Glucose in the amount of 5 percent increased the amount of digestible nitrogen-free extract, without adversely affecting the digestibility of protein or crude fiber. Starch had a similar effect. Corn oil in the amount of 5 percent also increased the amount of digestible organic matter largely through its contribution of digestible ether extract. Although the oil decreased digestibility of crude fiber and nitrogen-free extract such decreases were small being between 2 and 3 percentage units.

The nitrogen retention results are similar in some respects to those obtained with the same supplements added in equal and larger amounts to similar wintering-type rations; increases in nitrogen retention were effected through a decrease in urinary nitrogen loss.

A decrease in cellulose digestion as a result of adding 10 percent fat (corn oil) to a wintering-type ration was demonstrated using *in vitro* techniques. This decrease was partially alleviated by the addition of calcium, magnesium or iron.

LITERATURE CITED

Brethour, J. R., R. J. Sirny and A. D. Tillman. 1958. Further studies concerning the effects of fat in sheep rations. J. Animal Sci. 17:171.

Briggs, H. M. 1937. The effect of molasses on the digestibility of a lamb fattening ration. Proc. Amer. Soc. Animal Prod. p. 145.

Briggs, H. M. and V. G. Heller. 1949. The effect of adding blackstrap molasses to a lamb-fattening ration. J. Agr. Res. 60:65.

Brooks, C. C., C. B. Gainer, C. W. Gehrke, M. E. Muhrer and W. H. Pfander. 1954. The effect of added fat on the digestion of cellulose and protein by ovine rumen microorganisms. J. Animal Sci. 13:758.

Burroughs, Wise, Paul Gerlaugh, B. H. Edgington and R. M. Bethke. 1949. The influence of corn starch upon roughage digestion in cattle. J. Animal Sci. 8:271.

Chappel, C. F. 1952. Factors affecting the digestibility of low quality roughages by lambs. Ph. D. Thesis, Okla. State Univ.

Cheng, E. W., Glen Hall and Wise Burroughs. 1955. A method for the study of cellulose digestion by washed suspensions of rumen microorganisms. J. Dairy Sci. 38:1225.

Colovos, N. F., H. A. Keener, J. R. Prescott and A E. Teeri. 1949. The nutritive value of wood molasses as compared with cane molasses. J. Dairy Sci. 32:907.

Davison, K. L. and Walter Woods. 1959. Calcium carbonate and corn oil influences upon ration digestibility in lambs. J. Animal Sci. 18:1490.

Erwin, E. S., I. A. Dyer and M. E. Ensminger. 1956a. Effects of chlorotetracycline, inedible animal fat, stilbesterol and high and low quality roughage on performance of yearling steers. I. Feed consumption and rates of gain. J. Animal Sci. 15:710.

Erwin, E. S., I. A. Dyer and M. E. Ensminger. 1956b. Effects of chlorotetracycline, inedible animal fat, stilbesterol and high and low quality roughage on performance of yearling steers. II. Digestibility of dry matter, crude fiber, crude protein, and ether extract. J. Animal Sci. 15:717.

Fontenot, J. P. 1953. Supplements of different protein content for wintering beef cattle. M.S. Thesis, Okla. State Univ.

Fontenot, J. P., Willis D. Gallup and A. B. Nelson. 1955. Effect of added carbohydrate on the utilization by steers of nitrogen in wintering rations. J. Animal Sci. 14:807.

Grainger, R. B., T. W. White, F. H. Baker and J. W. Stroud. 1957. The interrelationship between calcium and fat in ruminant digestion. J. Animal Sci. 16:1086.

Hale, W. H. and R. P. King. 1955. The effect of added fat on the digestibility of lamb rations. J. Animal Sci. 14:1205.

Hamilton, T. S. 1942. The effect of added glucose upon the digestibility of protein and of fiber in rations for sheep. J. Nutr. 23:101.

Hentges, J. F., Jr., A. M. Pearson and C. A. Gucker. 1954. Waste beef fat in steer fattening rations and its effect upon the carcass. J. Animal Sci. 13:970.

Hubbard, D. D. 1957. The effect of high levels of energy on nitrogen utilization and digestibility of wintering rations by steers. M.S. Thesis, Okla. State Univ.

Hubbert, Farris, Edmund Cheng and Wise Burroughs. 1958. Mineral requirement of rumen microorganisms for cellulose digestion <u>in vitro</u>. J. Animal Sci. 17:559.

Jones, J. H., R. E. Dickson, J. K. Riggs and J. M. Jones. 1942. Silage and cottonseed meal for fattening yearling steers. Tex. Agr. Exp. Sta. Bul. 662.

Kammlade, W. G., Jr. and O. D. Butler. 1954. The use of animal fats in lamb feeding. Tex. Agr. Exp. Sta. Prog. Rpt. 1644.

Lindsey, J. B. and P. H. Smith. 1910. Effect of Puerto Rico molasses on digestibility of hay and hay and concentrates. Mass. Agr. Exp. Sta. 22nd Ann. Rpt. p. 82.

Lofgreen, G. P., J. K. Loosli and L. A. Maynard. 1951. The influence of energy intake on the nitrogen retention of growing calves. J. Dairy Sci. 34:911.

Lucas, H. L. and J. K. Loosli. 1944. The effect of fat upon the digestion of nutrients by dairy cows. J. Animal Sci. 3:3.

Matsushima, J., T. W. Dowe and V. H. Arthaud. 1953. Urea, beef tallow and corn oil for fattening cattle. Neb. Agr. Exp. Sta. Cattle Prog. Rpt. 219.

Matsushima, J., T. W. Dowe, V. H. Arthaud and C. H. Adams. 1955. The use and value of beef tallow in cattle fattening rations. Neb. Agr. Exp. Sta. Cattle Prog. Rpt. 227.

Matsushima, J., T. W. Dowe, R. W. Rice and V. H. Arthaud. 1957. The effect of various protein-energy ratios for fattening cattle. Neb. Agr. Exp. Sta. Cattle Prog. Rpt. 244.

Mitchell, H. H. 1924. A method of determining the biological value of protein. J. Biol. Chem. 58:873.

Mitchell, H. H., T. S. Hamilton and W. T. Haines. 1940. The utilization by calves of energy in rations containing different percentages of protein and glucose supplements. J. Agr. Res. 61:847.

Munro, H. N. 1951. Carbohydrate and fat as factors in protein utilization and metabolism. Physiol. Rev. 31:449.

Nelson, A. B., A. D. Tillman, W. D. Gallup and Robert MacVicar. 1954. A modified metabolism stall for steers. J. Animal Sci. 13:504.

Patterson, H. J. and Raymond Outwater. 1907. The digestibility of molasses feeds. Md. Agr. Exp. Sta. Bul. 117.

Pfander, W. H. and J. S. Verma. 1957. Physical factors that influence the response of sheep to added corn oil. J. Animal Sci. 16:1087.

Rhodes, R. W., F. H. Baker and R. B. Grainger. 1956. The alleviation of dietary fat inhibition of protein and cellulose digestion in sheep. J. Animal Sci. 15:1247.

Robinson, N. W. 1958. The effect of added fat and corn on the utilization by steers of nitrogen in wintering rations. Ph. D. Thesis, Okla. State Univ.

Schweigert, B. S. and O. H. M. Wilder. 1954. Utilization of animal fats by beef cattle. Ann. Rpt. Amer. Meat Inst. Found. Bul. 22 p. 28.

Summers, C. E., F. H. Baker and R. B. Grainger. 1956. The cellulolytic interrelationships of dietary fat, carbohydrates and minerals in sheep metabolism studies. J. Animal Sci. 15:1247.

Swift, R. W., E. J. Thacker, A. Black, J. W. Bratzler and W. H. James. 1947. Digestibility of rations for ruminants as affected by proportions of nutrients. J. Animal Sci. 6:432.

Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek. 1948. The effect of dietary fat on utilization of the energy and protein of rations by sheep. J. Animal Sci. 7:475.

Tillman, Allen D. and John R. Brethour. 1958. The effect of corn oil upon the metabolism of calcium and phosphorus by sheep. J. Animal Sci. 17:782.

Ward, J. K., C. W. Tefft, R. J. Sirny, H. N. Edwards and A. D. Tillman. 1957. Further studies concerning the effect of alfalfa ash upon the utilization of low-quality roughages by ruminant animals. J. Animal Sci. 16:633.

White, T. W., R. B. Grainger, F. H. Baker and J. W. Stroud. 1958. Effect of supplemental fat on digestion and the ruminal calcium requirement of sheep. J. Animal Sci. 17:797.

Willey, N. B., J. K. Riggs, R. W. Colby, O. D. Butler, Jr., and R. Reiser. 1952. The influence of level of fat and energy in the ration upon feedlot performance and carcass composition of fattening steers. J. Animal Sci. 11:705.

Williams, Paul S. 1924. The effect of cane molasses on the digestibility of a complete ration fed to dairy cows. J. Dairy Sci. 8:94.

Williams, V. J., M. C. Nottle, R. J. Moir and E. J. Underwood. 1953. Ruminal flora studies in the sheep. IV. The influence of varying dietary levels of protein and starch upon digestibility, nitrogen retention, and the free microorganisms of the rumen. Austral. J. Biol. Sci. 6:142.

Woods, Walter R., Charles M. Thompson and Robert B. Grainger. 1956. The effect of varying levels of protein and cerelose on the utilization of mature timothy hay by sheep. J. Animal Sci. 15:1141.

Willey, N. B., J. K. Riggs, R. W. Colby, O. D. Butler, Jr., and R. Reiser. 1952. The influence of level of fat and energy in the ration upon feedlot performance and carcass composition of fattening steers. J. Animal Sci. 11:705.

Williams, Paul S. 1924. The effect of cane molasses on the digestibility of a complete ration fed to dairy cows. J. Dairy Sci. 8:94.

Williams, V. J., M. C. Nottle, R. J. Moir and E. J. Underwood. 1953. Ruminal flora studies in the sheep. IV. The influence of varying dietary levels of protein and starch upon digestibility, nitrogen retention, and the free microorganisms of the rumen. Austral. J. Biol. Sci. 6:142.

Woods, Walter R., Charles M. Thompson and Robert B. Grainger. 1956. The effect of varying levels of protein and cerelose on the utilization of mature timothy hay by sheep. J. Animal Sci. 15:1141.

A P P E N D I X

TABLE I

Daily Nitrogen Balance and Biological Value Data for Experiment 1

Ration	Trial no.	Steer no.	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention	Nitrogen retention	Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
			gm	gm	gm	gm	gm	%	gm	gm	gm	gm	%
Basal	1	1	3627.8	99.2	29.6	61.3	8.4	8.4	19.2	7.9	88.9	35.5	39.9
	1	2	3627.8	99.2	39.1	49.3	10.8	10.9	19.2	7.5	79.4	37.5	47.3
	1	5	3627.8	99.2	28.0	50.6	20.6	20.8	19.2	7.0	90.5	46.9	51.8
	1	7	3627.8	99.2	30.4	48.7	20.1	20.2	19.2	7.5	88.1	46.8	53.2
	1	8	3627.8	99.2	29.9	49.4	19.9	20.0	19.2	7.6	88.5	46.7	52.8
	1	10	3627.8	99.2	30.0	49.9	19.4	19.5	19.2	7.9	88.5	46.5	52.5
	2	3	3561.2	96.9	26.7	52.9	17.3	17.9	18.9	7.5	89.1	43.7	49.0
	2	4	3561.2	96.9	27.6	51.6	17.7	18.3	18.9	7.4	88.2	44.0	49.9
	2	6	3561.2	96.9	25.2	59.3	12.4	12.8	18.9	7.6	90.6	38.9	42.9
	2	9	3561.2	96.9	29.0	54.1	13.8	14.3	18.9	7.5	86.8	40.2	46.3
	2	11	3561.2	96.9	29.2	55.7	12.0	12.4	18.9	7.6	86.6	38.5	44.4
	2	12	3561.2	96.9	27.3	52.4	17.2	17.7	18.9	7.8	88.4	43.9	49.6
		Av.	3594.5	98.0	29.3	52.9	15.8	16.1	19.0	7.6	87.8	42.4	48.3
Basal + corn oil	1	3	4027.8	99.2	29.4	47.7	22.1	22.3	21.4	7.5	91.2	51.0	55.9
	1	4	4027.8	99.2	31.5	44.2	23.5	23.7	21.4	7.4	89.0	52.2	58.7
	1	6	4027.8	99.2	34.5	49.2	15.5	15.7	21.4	7.6	86.1	44.5	51.7
	1	9	4027.8	99.2	31.5	52.4	15.4	15.5	21.4	7.5	89.1	44.3	49.7
	1	11	4027.8	99.2	31.8	53.8	13.6	13.8	21.4	7.6	88.8	42.6	47.9
	1	12	4027.8	99.2	31.4	48.6	19.2	19.3	21.4	7.8	89.1	48.4	54.3
	2	1	3961.2	96.9	28.6	60.2	8.0	8.3	21.0	7.9	89.2	36.9	41.4
	2	2	3961.2	96.9	28.5	51.2	17.2	17.7	21.0	7.5	89.4	45.6	51.1
	2	5	3961.2	96.9	28.0	53.3	15.6	16.1	21.0	7.0	89.9	43.6	48.5
	2	7	3961.2	96.9	28.8	60.5	7.6	7.9	21.0	7.5	89.1	36.1	40.5
	2	8	3961.2	96.9	26.6	50.9	19.4	20.0	21.0	7.6	91.3	47.9	52.5
	2	10	3961.2	96.9	28.2	54.8	13.8	14.3	21.0	7.9	89.6	42.7	47.6
		Av.	3994.5	98.0	29.9	52.2	15.9	16.2	21.2	7.6	89.3	44.6	50.0

TABLE II

Digestibility Data obtained with Steers fed the Basal and Supplemented Rations in Experiment 1

Ration	Trial no.	Steer no.	Dry matter intake	Fecal ash	Calcium excretion	Apparent percent digestibility: Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	T.D.N.
			gm	gm	gm							%
Basal	1	1	3627.8	199.8	16.5	63.3	66.1	70.2	78.2	69.5	62.0	63.2
	1	2	3627.8	181.7	13.9	63.1	65.3	60.7	74.3	66.6	65.9	62.4
	1	5	3627.8	185.8	16.6	62.0	64.3	71.8	71.7	64.8	60.8	61.4
	1	7	3627.8	195.4	17.7	63.2	65.9	69.4	58.8	69.5	62.9	62.5
	1	8	3627.8	182.2	16.6	63.0	65.2	69.9	52.4	67.8	62.8	61.6
	1	10	3627.8	192.8	16.3	61.9	64.4	69.8	48.4	66.2	62.7	61.1
	2	3	3561.2	193.1	18.6	60.2	62.8	72.5	43.7	62.3	60.7	59.6
	2	4	3561.2	191.2	16.7	61.9	64.6	71.5	49.8	67.7	61.0	61.4
	2	6	3561.2	187.8	16.5	63.6	66.3	74.0	49.9	68.8	62.9	63.0
	2	9	3561.2	180.6	17.2	63.9	66.4	70.1	45.9	68.6	64.9	62.9
	2	11	3561.2	203.0	19.0	61.0	64.0	69.9	41.2	67.3	61.2	60.6
	2	12	3561.2	197.5	19.2	62.1	65.0	71.8	50.6	66.1	62.6	61.8
	Av.		3594.5	190.9	17.1	62.4	65.0	71.1	55.4	67.1	62.5	61.8
Basal + corn oil	1	3	4027.8	192.8	15.4	55.5	57.2	70.4	81.8	48.8	49.9	65.5
	1	4	4027.8	191.9	14.9	58.4	60.3	68.3	81.6	54.2	54.5	68.3
	1	6	4027.8	204.0	15.4	54.9	56.9	65.3	75.8	52.2	50.9	63.8
	1	9	4027.8	192.8	16.5	53.5	55.1	68.4	81.1	47.9	46.7	63.4
	1	11	4027.8	195.4	16.8	52.8	54.3	68.0	80.1	45.6	46.6	62.6
	1	12	4027.8	190.7	16.9	53.3	54.7	68.3	83.7	45.0	46.7	63.5
	2	1	3961.2	216.5	20.8	56.5	59.2	70.4	80.4	53.4	51.9	67.7
	2	2	3961.2	204.9	18.3	54.5	56.7	70.6	81.7	47.3	49.5	65.6
	2	5	3961.2	207.0	18.8	55.0	57.4	71.1	79.3	51.8	48.9	65.9
	2	7	3961.2	195.0	18.8	56.8	58.9	70.3	81.7	55.6	49.7	67.7
	2	8	3961.2	205.6	16.5	55.8	58.2	72.5	83.1	50.0	50.1	67.2
	2	10	3961.2	188.2	18.2	55.7	57.6	70.9	81.5	49.0	50.5	66.4
	Av.		3994.5	198.7	17.3	55.2	57.2	69.5	80.9	50.1	49.7	65.6

TABLE III

Daily Nitrogen Balance and Biological Value Data for Experiment 2

Ration	Trial no.	Steer no.	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
			gm	gm	gm	gm	gm	%	gm	gm	gm	gm	%
Basal	1	1	3340.7	62.4	26.6	23.1	12.6	20.2	17.7	7.2	53.5	37.6	70.3
	1	7	3340.7	62.4	26.8	16.3	19.2	30.8	17.7	6.8	53.3	43.8	82.2
	2	6	3327.2	58.7	26.1	20.1	12.5	21.3	17.6	6.9	50.2	37.0	73.7
	2	9	3327.2	58.7	26.8	16.7	15.2	25.9	17.6	6.9	49.5	39.7	80.2
	3	2	3317.9	62.2	26.4	26.9	8.8	14.1	17.6	7.5	53.4	33.9	63.5
	3	5	3317.9	62.2	26.7	25.0	10.4	16.7	17.6	7.1	53.1	35.2	66.3
	4	8	3319.8	52.9	24.9	26.3	1.7	3.2	17.6	7.1	45.6	26.4	57.9
	4	12	3319.8	52.9	25.8	25.8	1.3	2.5	17.6	7.2	44.7	26.1	56.2
	Av.		3326.4	59.0	26.3	22.5	10.2	16.8	17.6	7.1	50.4	35.0	68.8
Basal + cerelose	1	2	3540.7	62.4	26.4	19.5	16.5	26.4	18.8	7.5	54.8	42.8	78.1
	1	5	3540.7	62.4	24.7	18.7	18.9	30.3	18.8	7.1	56.5	44.9	79.5
	2	8	3527.2	58.7	27.5	18.8	12.4	21.1	18.7	7.1	49.9	38.2	76.6
	2	12	3527.2	58.7	27.1	22.2	9.4	16.0	18.7	7.2	50.3	35.3	70.2
	3	6	3517.9	62.2	26.8	20.1	15.3	24.6	18.6	6.9	54.0	40.8	75.6
	3	9	3517.9	62.2	27.0	22.6	12.6	20.3	18.6	6.9	53.8	38.1	70.8
	4	1	3519.8	52.9	25.7	24.2	3.0	5.7	18.7	7.2	45.9	28.9	63.0
	4	7	3519.8	52.9	25.0	24.2	3.7	7.0	18.7	6.8	46.6	29.2	62.7
	Av.		3526.4	59.0	26.3	21.3	11.5	18.9	18.7	7.1	51.5	37.3	72.1
Basal + starch	1	8	3540.7	62.4	25.0	19.2	18.1	29.0	18.7	7.1	56.1	40.0	71.3
	1	12	3540.7	62.4	26.0	18.0	18.4	29.5	18.7	7.2	55.1	44.3	80.4
	2	2	3527.2	58.7	25.7	20.6	12.4	21.1	18.8	7.5	51.8	38.7	74.7
	2	5	3527.2	58.7	25.7	19.2	13.8	23.5	18.8	7.1	51.8	39.7	76.6
	3	1	3517.9	62.2	27.2	21.9	13.0	20.9	18.7	7.2	53.7	39.0	72.6
	3	7	3517.9	62.2	26.3	22.7	13.2	21.2	18.7	6.8	54.6	38.7	70.9
	4	6	3519.8	52.9	23.7	27.0	2.3	4.3	18.6	6.9	47.8	27.7	57.9
	4	9	3519.8	52.9	24.7	22.6	5.7	10.8	18.6	6.9	46.8	31.1	66.5
	Av.		3526.4	59.0	25.5	21.4	12.1	20.0	18.7	7.1	52.2	37.4	71.4

TABLE III (continued)

Ration	Trial no.	Steer no.	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
			gm	gm	gm	gm	gm	%	gm	gm	gm	gm	%
Basal +	1	6	3540.7	62.4	25.5	19.4	17.4	27.9	18.6	6.9	55.5	43.0	77.5
corn oil	1	9	3540.7	62.4	27.1	14.5	20.8	33.3	18.6	6.9	53.9	46.3	85.9
	2	1	3527.2	58.7	26.8	18.6	13.3	22.7	18.7	7.2	50.9	39.2	77.0
	2	7	3527.2	58.7	27.1	16.7	14.8	25.2	18.7	6.8	50.3	40.4	80.3
	3	8	3517.9	62.2	26.9	23.0	12.3	19.8	18.7	7.1	54.0	38.1	70.6
	3	12	3517.9	62.2	25.7	17.6	18.8	30.2	18.7	7.2	55.2	44.8	81.2
	4	2	3519.8	52.9	26.8	23.1	3.0	5.7	18.8	7.5	44.9	29.3	65.3
	4	5	3519.8	52.9	26.2	23.3	3.4	6.4	18.8	7.1	45.5	29.3	64.4
		Av.	3526.4	59.0	26.5	19.5	13.0	21.4	18.7	7.1	51.3	38.8	75.3

TABLE IV

Digestibility Data Obtained with Steers Fed the Basal and Supplemented Rations in Experiment 2

Ration	Trial no.	Steer no.	Dry matter intake	Fecal ash	Calcium excretion	Apparent percent digestibility: Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	% T.D.N.
			gm	gm	gm							
Basal	1	1	3340.7	195.6	18.6	58.5	61.5	57.4	48.1	63.2	62.1	58.5
	1	7	3340.7	189.6	15.6	57.5	60.2	56.9	47.2	60.1	61.7	57.3
	2	6	3327.2	186.4	16.0	57.2	59.5	55.7	44.7	59.7	61.0	56.0
	2	9	3327.2	179.2	14.1	60.3	62.7	54.4	44.3	64.4	64.4	58.9
	3	2	3317.9	191.3	12.8	59.4	62.1	57.6	49.0	64.8	62.1	58.6
	3	5	3317.9	191.7	14.4	61.3	64.2	57.0	56.0	69.5	63.0	60.7
	4	8	3319.8	171.7	14.6	63.3	65.6	53.0	63.5	69.6	65.7	62.2
	4	12	3319.8	186.6	15.4	61.6	64.2	51.3	52.7	66.7	65.9	60.5
	Av.		3326.4	186.5	15.2	59.9	62.5	55.4	50.7	64.7	63.2	59.1
Basal + cerelose	1	2	3540.7	186.3	--	64.2	67.1	57.9	62.5	66.1	69.9	64.4
	1	5	3540.7	179.9	--	63.6	66.3	60.3	54.9	65.3	68.7	63.4
	2	8	3527.2	191.8	--	62.9	65.7	53.1	43.6	66.4	68.8	61.9
	2	12	3527.2	175.5	--	63.1	65.4	53.9	49.1	64.6	68.8	61.8
	3	6	3517.9	188.1	--	63.3	66.1	57.0	46.7	66.7	68.5	62.2
	3	9	3517.9	197.2	--	59.9	62.7	56.7	31.0	64.0	64.6	58.8
	4	1	3519.8	177.4	--	63.6	66.0	51.4	55.9	66.7	68.8	62.5
	4	7	3519.8	168.9	--	66.0	68.4	52.8	61.9	71.0	70.0	64.8
	Av.		3526.4	183.1		63.3	66.0	55.4	50.7	66.3	68.5	62.5
Basal + starch	1	8	3540.7	179.5	--	62.0	65.7	59.9	49.9	64.1	68.5	62.6
	1	12	3540.7	180.1	--	60.7	64.4	58.5	56.8	63.2	66.6	61.6
	2	2	3527.2	190.6	--	62.7	65.4	56.3	44.9	64.4	68.7	61.7
	2	5	3527.2	181.2	--	64.0	66.6	56.5	48.0	67.0	69.2	62.8
	3	1	3517.9	180.6	--	63.3	65.9	56.2	47.1	68.0	67.6	62.3
	3	7	3517.9	180.1	--	62.6	65.1	57.7	46.3	61.8	67.3	60.4
	4	6	3519.8	158.1	--	64.6	66.5	55.3	62.1	67.3	68.3	63.1
	4	9	3519.8	171.1	--	64.8	67.1	53.5	56.8	67.2	70.0	63.5
	Av.		3526.4	177.7		63.1	65.8	56.7	51.5	65.4	68.3	62.2

TABLE IV (continued)

Ration	Trial no.	Steer no.	Dry matter intake	Fecal ash	Calcium excretion	Apparent percent digestibility: Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	% T.D.N.
			gm	gm	gm							
Basal +	1	6	3540.7	182.7	14.5	56.0	58.2	59.0	78.5	54.4	56.8	62.2
corn oil	1	9	3540.7	176.5	13.0	57.9	60.1	56.5	77.5	57.8	59.2	63.8
	2	1	3527.2	177.5	15.0	60.6	62.8	54.4	78.6	62.3	62.2	65.8
	2	7	3527.2	196.5	15.9	57.5	60.0	53.8	80.6	57.8	59.2	63.4
	3	8	3517.9	185.3	13.7	58.9	61.3	56.7	80.3	62.6	60.0	65.4
	3	12	3517.9	176.5	13.2	61.3	63.6	58.7	80.3	64.6	61.3	66.7
	4	2	3519.8	172.6	14.5	64.1	66.4	49.3	83.7	68.7	65.3	69.6
	4	5	3519.8	167.7	16.2	63.9	66.0	50.4	85.4	66.8	65.3	69.4
	Av.		3526.4	179.4	14.5	60.0	62.3	54.8	80.6	61.9	61.2	65.8

TABLE V

Steer Weights

Experiment 1

Steer	Initial weight	Final weight	Change
1	675	600	-75
2	595	610	15
3	595	670	75
4	580	610	30
5	510	540	30
6	620	575	-45
7	600	600	0
8	615	650	35
9	600	585	-15
10	675	670	- 5
11	615	610	- 5
12	665	625	-40

Experiment 2

Steer	Initial weight	Final weight	Change
1	535	550	15
2	580	590	10
5	490	520	30
6	495	500	5
7	485	475	-10
8	490	520	30
9	530	500	-30
12	550	550	0

TABLE VI

Cellulose Digestion Data Obtained From Artificial Rumen Studies in Experiment 3

	Basal				Basal + corn oil			
Treatment	Cellulose	Cellulose + Iron	Cellulose + Calcium	Cellulose + Magnesium	Cellulose	Cellulose + Iron	Cellulose + Calcium	Cellulose + Magnesium
Trial I	72.0	65.3	73.3	72.7	22.7	23.5	58.2	25.5
II	80.5	62.0	73.1	74.5	19.3	23.0	43.7	30.5
III	81.8	69.5	73.1	78.6	23.6	25.2	34.4	33.2
IV	73.1	67.1	75.2	73.2	17.2	21.6	25.9	26.0
Average	76.8	66.0	73.7	74.7	20.2	23.3	40.5	28.8

TABLE VII

Summary of Results Obtained at the Oklahoma Agricultural Experiment Station in Adding Carbohydrate and Fat Supplements to Wintering Rations for Steers

Source of Energy	Intake					Excretion		True digested N	Nitrogen retention
	Dry matter	Supplement		Protein	Nitrogen	Fecal N	Urinary N		
	gm	gm	%	%	gm	gm	gm	gm	gm
[1] Basal ration-prairie hay 2,724 gm, cottonseed meal 270 gm, salt 25 gm, dicalcium phosphate 25 gm, monosodium phosphate 10 gm. Average steer weight 515 lbs. (Fontenot *et al.*, 1955)									
	2884.1	0	.0	8.4	38.5	18.4	14.0	35.4	6.1
Glucose	3204.9	350	11.6	7.5	38.6	19.5	13.1	36.1	5.9
	3482.2	700	23.1	6.9	38.3	21.4	12.1	35.3	4.7
	3757.0	1050	34.7	6.3	37.9	21.8	11.8	35.9	4.2
[2] Basal ration-prairie hay 2734 gm, cottonseed meal 404 gm, salt 25 gm, steamed bonemeal 16 gm, monosodium phosphate 16 gm. Average steer weight 540 lbs. (Fontenot *et al.*, 1955)									
	2869.3	0	0	9.8	44.7	20.1	18.0	39.9	6.7
Glucose	3531.2	700	21.9	8.0	45.6	23.1	13.8	41.2	8.7
	3830.3	1050	32.9	7.4	45.4	23.8	13.8	41.9	7.8
[3] Basal ration-prairie hay 2734 gm, cottonseed meal 600 gm, salt 25 gm, steamed bonemeal 14 gm, monosodium phosphate 8 gm. Average steer weight 530 lbs. (Fontenot *et al.*, 1955)									
	3096.2	0	0	11.8	58.4	23.0	22.7	51.9	12.7
Glucose	3719.8	700	20.7	9.8	58.2	28.0	17.2	49.9	13.0
	4020.4	1050	31.1	8.9	57.8	28.3	15.7	50.8	13.8
[4] Basal ration-prairie hay 3000 gm, cottonseed meal 454 gm, salt 25 gm, dicalcium phosphate 25 gm. Average steer weight 483 lbs. (Robinson, 1958)									
Corn	3325.3	0	0	9.58	50.6	22.0	16.3	46.1	12.2
	3679.6	572[a]/	16.9	8.62	50.3	24.8	14.2	45.0	11.3

TABLE VII (continued)

Source of Energy	Intake: Dry matter	Supplement		Protein	Nitrogen	Excretion: Fecal N	Urinary N	True digested N	Nitrogen retention
	gm	gm		%	gm	gm	gm	gm	gm
	[5] Basal ration-prairie hay 3000 gm, cottonseed meal 600 gm, salt 25 gm, dicalcium phosphate 25 gm. Average steer weight 642 lbs. (Hubbard, 1957)								
Starch	3389.1	0	0	11.1	60.6	25.2	29.7	53.2	5.6
	3837.4	440	12.1	9.9	60.6	27.4	23.5	53.6	9.8
	[6] Basal ration-prairie hay 3000 gm, cottonseed meal 585 gm, corn 323 gm, salt 25 gm, dicalcium phosphate 25 gm. Average steer weight 625 lbs. (Hubbard 1957)								
Corn oil	3742.7	0	0	10.9	65.1	27.9	23.2	57.0	13.9
	4182.7	440	11.1	9.7	65.1	28.6	22.3	58.7	14.1
	[7] Basal ration-prairie hay 3000 gm, cottonseed meal, 454 gm, Drackett 350 gm, salt 25 gm, dicalcium phosphate 25 gm. Average steer weight 612 lbs. (Hubbard, Experiment I)								
Corn oil	3594.5	0	0	17.1	98.0	29.3	52.9	87.8	15.8
	3994.5	400	10.4	15.4	98.0	29.9	52.2	89.3	15.9
	[8] Basal ration-prairie hay 3000 gm, cottonseed meal 454 gm, salt 25 gm, dicalcium phosphate 25 gm. Average steer weight 508 lbs. (Robinson, 1958)								
Corn oil	3260.0	0	0	10.1	52.4	23.4	17.5	46.2	11.5
	3464.0	200	5.7	9.7	52.6	23.9	15.5	47.1	13.3

TABLE VII (continued)

Source of Energy	Intake					Excretion		True digested N	Nitrogen retention
	Dry matter	Supplement		Protein	Nitrogen	Fecal N	Urinary N		
	gm	gm		%	gm	gm	gm	gm	gm
9 Basal ration-prairie hay 3000 gm, cottonseed meal 500 gm, salt 25 gm, dicalcium phosphate 25 gm. Average steer weight 526 lbs. (Hubbard, Experiment II)									
	3326.4	0	0	11.1	59.0	26.3	22.5	50.4	10.2
Glucose	3526.4	200	5.6	10.5	59.0	26.3	21.3	51.5	11.5
Starch	3526.4	200	5.6	10.5	59.0	25.5	21.4	52.2	12.1
Corn oil	3526.4	200	5.6	10.5	59.0	26.5	19.5	51.3	13.0

a Replaced 118 gm cottonseed meal in the basal, equivalent to 355 gm (10.1%) non nitrogenous nutrients

Summary of Oklahoma Work (Continued)

It appears from the summary of results obtained at the Oklahoma Agricultural Experiment Station that nitrogen retention of steers fed a wintering-type ration of prairie hay and cottonseed meal can be increased by addition of energy supplements. However, the initial percent of protein in the ration as well as the percent of added supplement must be considered.

The addition of energy decreased urinary nitrogen in all of the experiments; however, it generally increased fecal nitrogen, the kind and level of energy supplement determining the magnitude of this increase. With glucose or starch as the supplement, the increase in fecal nitrogen excretion was roughly proportional to the amount added. With corn oil as the supplement, fecal nitrogen was not significantly affected. The magnitude and direction of the changes in nitrogen excretion were such that a high level (10 percent and above) of carbohydrate (glucose and starch) or a low level of corn oil (5 percent) significantly improved nitrogen retention. A high level of corn oil (10 percent) and a low level of carbohydrate (5 percent, glucose and starch) had no significant effect on nitrogen retention; they decreased urinary nitrogen an insignificant amount.

"True" digested nitrogen, or absorbed feed nitrogen, calculated by correction of total fecal nitrogen for metabolic nitrogen (5.3 gm. per kg dry matter) was not significantly altered by carbohydrate or fat additions. The constancy of these values within each experiment permits interpretation of decreases in urinary nitrogen values as representing, with few exceptions, improved utilization of absorbed feed nitrogen with each energy addition. To describe the results obtained with the high levels of carbohydrate as an expression of "the protein-sparing action of carbohydrate", in the broadest sence of the term, would be a paradox, since at high levels, both glucose and starch while sparing nitrogen in metabolism wasted nitrogen in digestion. At low levels, carbohydrate did not waste nitrogen in digestion, but its sparing action in metabolism was not sufficient to effect a significant increase in nitrogen retention. Although high levels of corn oil had little if any effect on nitrogen digestion or metabolism, low levels significantly increased nitrogen retention by sparing nitrogen in metabolism while nitrogen digestion was not appreciably affected. Thus, low levels of corn oil could be said to have a true protein sparing action when added to a wintering-type ration of prairie hay and cottonseed meal.

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